JOURNAL OF AGRICULTURAL RESEARCH

VOL. XI WASHINGTON, D. C., DECEMBER 24, 1917 NO. 13

STRUCTURE OF THE POD AND THE SEED OF THE GEORGIA VELVET BEAN, STIZOLOBIUM DEERINGIANUM

By CHARLES V. PIPER, *Agrostologist in Charge, Forage-Crop Investigations,* and J. MARION SHULL, *Botanical Artist, Fruit Disease Investigations, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

Since 1915 the culture of the velvet bean in the South has been very greatly increased, mainly owing to the introduction and development of short-season varieties. The early sorts are the Yokohama bean (*Stizolobium hassjoo* Piper and Tracy); the Chinese velvet bean (*S. niveum* (Roxb.) Kuntze var.); the Georgia velvet bean, an early variety of the old Florida velvet bean (*S. deeringianum* Bort); and also several varieties of hybrid origin. The Georgia velvet bean is at present the most largely grown. In 1916 the crop of beans reached such large proportions that numerous mills found it profitable to manufacture velvet-bean meal, prepared by grinding the dry ripe pods and seeds. This product has met with high favor as a rich protein feed. The acreage of velvet beans planted in 1917 is several times larger than in 1916.

No previous studies seem to have been made of the microscopic structure of the velvet bean, or, indeed, of any species of Stizolobium. The structure of other leguminous seeds has been described and illustrated by various botanists, particularly Kondo.[1] Inasmuch as velvet-bean meal promises to become an important commercial feed, the microscopic structures of the pod and seed are important as a basis of identifying the meal, either pure, adulterated, or in mixtures.[2]

STRUCTURE OF THE POD

HAIRS (Pl. 50, G).—The hairs on the surface of the pod consist of a long terminal cell, empty or apparently so, and one to six very short basal cells filled with protoplasm. The hairs vary greatly in length,

[1] KONDO, M. DER ANATOMISCHE BAU EINIGER AUSLÄNDISCHER HÜLSENFRÜCHTE, DIE JETZT IN DEN HANDEL KOMMEN. *In* Ztschr. Untersuch. Nahr. u. Genussmtl., Bd. 25, Heft 1, p. 1–56, 40 fig. 1913.

[2] The microscopic preparations of the material were made mostly by Dr. Albert Mann, of the Bureau of Plant Industry, and the drawings are all by the junior writer.

from 300 to 1,500 μ. The surface of the hairs is roughened with minute tubercles, increasingly so toward the apex. The smaller hairs are colorless, and on account of a relatively thicker wall remain cylindric, while the larger ones collapse and become blackish and twisted.

CARPELLARY WALL (Pl. 50, C, G).—The wall of the pod consists of an outer layer of epidermal cells, polyhedral in form, 15 to 30 μ thick, approximately cubical, and 15 to 30 μ in diameter. They are filled with dense protoplasm. The numerous basal cells of the hairs are conspicuous on account of the black base of the hairs. Stomata of typical form are about one-half as numerous as the hair bases.

Beneath the epidermis lie about five layers of peculiar sclerenchyma cells (Pl. 50, G, H, I, J) from 50 to 234 μ in length. The cells are spindle-shaped, and two to six times as long as broad, the lumen broadening at each end.

The inner half of the pod consists of small-celled parenchyma and numerous longitudinal bundles of thick-walled fibers (Pl. 50, D, E, F, G), 300 to 500 μ long. The lumen of these fibers is small, and in section numerous lateral extensions are apparent.

The innermost layer of the pod is satinlike and consists of thin-walled parenchyma (Pl. 50, A).

The fibrovascular bundles which traverse the pod require no particular mention. Their structure in cross section is illustrated in Plate 50, B.

STRUCTURE OF THE SEED

The most characteristic external feature of the seed of the velvet bean is the thick, white caruncle which surrounds the hilum (Pl. 51, A). In cross section (Pl. 51, B) this is seen to be composed of thick-walled parenchyma.

TESTA.—In cross section (Pl. 51, B, E) the testa is seen to be composed of an outer layer of long palisade cells, a second layer of the so-called "hour-glass" cells, the central portion of nearly empty parenchyma, and, between this and the small-celled inner epidermis, several layers of parenchyma filled with protein.

The palisade cells (Pl. 51, C, D) are thick-walled cylinders, 100 to 180 μ long and 10 to 22 μ in diameter. In the neighborhood of the hilum the palisade cells are longest and broken near the middle by the so-called "light line," owing to the fact that these cells have the lumen much enlarged near the middle.

The hour-glass cells (Pl. 51, F, G) are 50 to 100 μ long. They closely resemble those of related genera (Phaseolus, Vigna, Soja).

The cotyledons (Pl. 51, I, J) consist mainly of an outer epidermis of polyhedral cells about 10 μ in diameter; an inner epidermis of cells more than twice as large; and between, the much larger cells of the body of the cotyledons. All the cells are filled with grains of starch and proteids. The starch grains show no special peculiarities.

CHARACTERISTIC ELEMENTS

In velvet-bean meal the most abundant recognizable elements are: (1) The palisade cells of the testa; (2) the sclerenchyma cells of the pod; (3) the hairs of the pod, and (4) an occasional hour-glass cell. Most of the fibers are broken, but with careful examination nearly all of the structures may be found.

The most important elements to determine that the material is composed of velvet beans are the sclerenchyma cells and the hairs of the pods.

PLATE 50

A.—Thin-walled parenchyma forming the satin tissue that lines the pod. ×80.

B.—Cross section of a vascular bundle of the pod. ×420.

C.—Section of epidermis of pod, showing a stoma and several of the basal cells from which the hairs arise. ×80.

D.—Fiber cells. ×80.

E.—Fiber cell in longitudinal section. ×420.

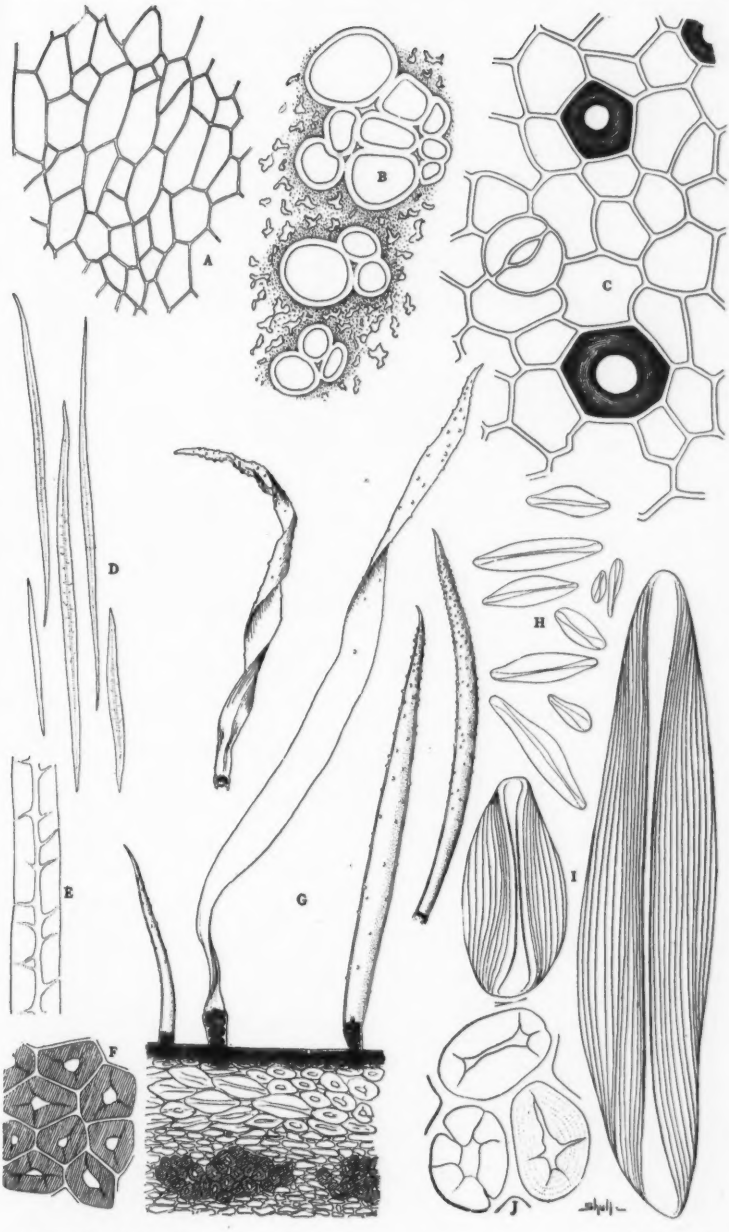
F.—Fiber cells in cross section. ×420.

G.—Cross section of velvet-bean pod, showing both conditions of surface hairs arising from the epidermal layer. Both types of hairs are of similar construction, being unicellular except at base, which consists variously of from one to five or six cells. The hairs are granulate or roughened, increasingly so toward the apex. The longer, weaker-walled hairs have collapsed and become twisted or otherwise deformed and darkened in color, while the shorter, heavier-walled hairs remain stiff, tubular bristles, straight or sickle-shaped, and transparent. Underlying the epidermis is the layer of sclerenchyma tissue several cells in depth, and below this appear fiber bundles in cross section. ×80.

H.—Sclerenchyma cells. ×80. These cells vary greatly in size, ranging from 50 to 234 μ in length.

I.—Sclerenchyma cells. ×420.

J.—Sclerenchyma cells in cross section. ×420.


A
B
C
D
E
F
G
H
I
J

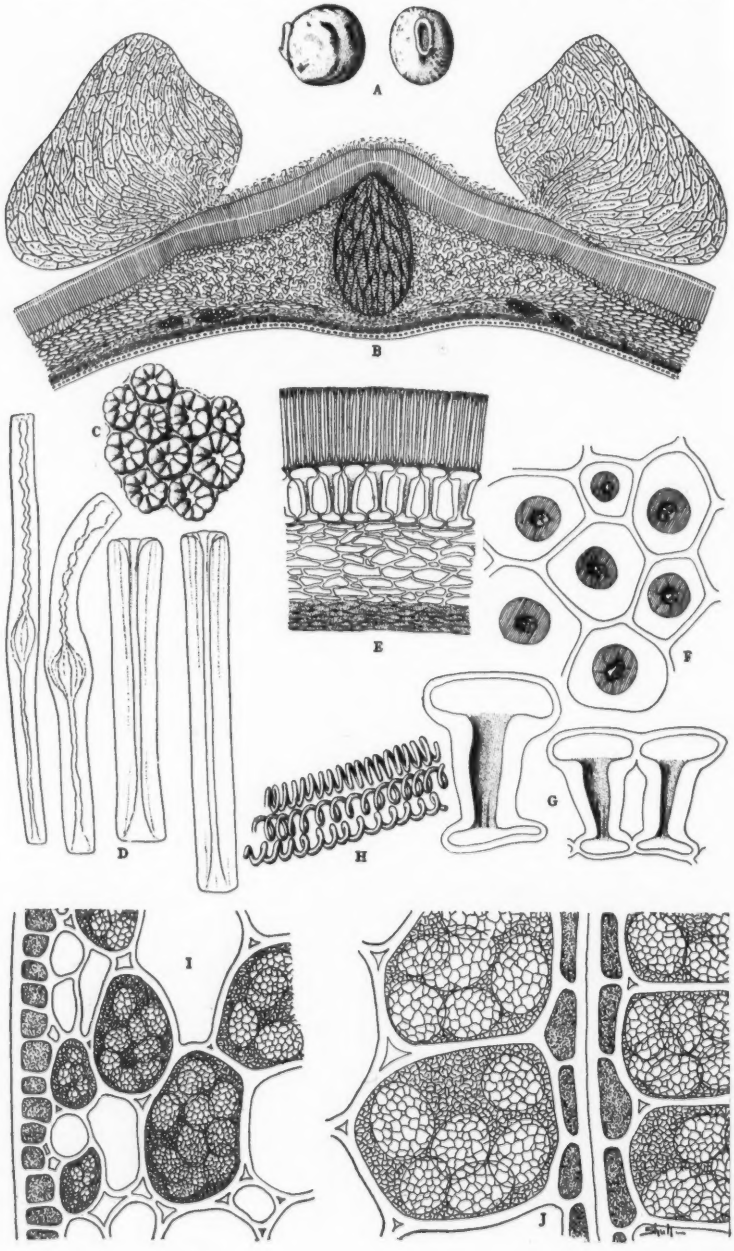

A
B
C
D
E
F
G
H
I
J

PLATE 51

A.—Georgia velvet bean. Natural size.

B.—Cross section through hilum showing thick-walled parenchyma of the caruncle and the very short palisade cells of the hilar tissues. Beneath these are the palisade cells of the seed coat with the "light line" sinking to near the middle of the cells under the hilum. To right and left of the large vascular bundle consisting of scalariform ducts are the lesser spiral vascular bundles of the inner seed coat. ×27.

C.—Palisade cells of seed coat, top view. ×420.

D.—Palisade cells of seed coat. The two cells on the left are from that part of the seed coat underlying the hilum and show the modification of the lumen that results in the so-called "light line." Palisade cells of the seed coat are 100 to 180 μ long and 10 to 22 μ wide. ×420.

E.—Cross section through seed coat elsewhere than at the hilum showing relationship of palisade cells, hour-glass cells, and the underlying parenchyma. ×80.

F.—Hour-glass cells seen from above. ×420.

G.—Hour-glass cells, side view. ×420.

H.—Spirals from vascular bundles of the seed coat. ×420.

I.—Cross section of cotyledon, showing outer epidermis, and smaller cells filled with starch grains and proteid granules. ×420.

J.—Cross section of cotyledons, showing the medial line of the two cotyledons with inner epidermis and adjoining much larger cells with starch grains and proteid granules correspondingly larger. ×420.

DECOMPOSITION OF GREEN AND STABLE MANURES IN SOIL

By R. S. POTTER, *Assistant Chief in Soil Chemistry*, and R. S. SNYDER, *Assistant in Soil Chemistry, Iowa State College Experiment Station*

HISTORICAL REVIEW

This paper is the third of a series of reports whose principal object is the determination of the rate of decomposition of original or added organic material in soil. This is done by the measurements at frequent intervals of the carbon dioxid evolved from manured and unmanured soils. In the first of these papers (*7*)[1] the effects of lime, ammonium sulphate, and sodium nitrate on carbon-dioxid production were determined. In the second paper (*8*) several phases of the subject were taken up, the more important of which are: (1) The relation of the amount of air drawn over soils to the amount of carbon dioxid evolved, (2) a determination of the percentage of carbon dioxid in plots treated with varying amounts and kinds of organic matter, (3) a comparison of the results obtained by the laboratory method for the determination of carbon dioxid evolved from soils to the results of the determination of the percentage of carbon dioxid in the atmosphere of soils in the field, and (4) determinations of the amount of carbon dioxid evolved from soils treated with lime and varying amounts of stable manure. The conclusions were briefly as follows: Within limits there was not much variation in the amount of carbon dioxid evolved from soil with different amounts of air passed over the soil. The results obtained by the laboratory method agreed well with those obtained in the field plots. Calcium carbonate accelerated the rate of decomposition of both the original organic matter of soil and that added in amounts of stable manure varying from 10 to 50 tons per acre. There was less calcium carbonate decomposed in those soils receiving applications of manure than in those unmanured.

A complete review of the work done in American Experiment Stations on green manuring published quite recently (*6*) calls attention to the fact that, while there are very little definite data concerning the effects of green manuring upon succeeding crop yields, yet the conclusion to be drawn from all the work done upon the subject is that in general green manuring increases crop yields. A common recommendation to farmers is to plow in green manure to build up the organic matter in the soil, but there is no definite information available as to how rapidly one may expect such a practice to build up the soil or as to how long, for instance, such

[1] Reference is made by number (italic) to "Literature cited", pp. 697–698.

Journal of Agricultural Research,
Washington, D. C.
II

Vol. XI, No. 13
Dec. 24, 1917
Key No. Iowa–5

an application will last. It was to throw some light on this phase of the green manuring problem that the work reported herein was undertaken.

In one of the papers referred to above (*8*) a quite complete review of the literature on carbon-dioxid production in soils is given, so that here mention will be made of only those papers which have appeared since the preparation of that bibliography.

J. G. Lipman and associates (*4*) have at various times reported the results of a field experiment on the effect of a light application of stable manure on the decomposition of green manures. The essential points of the plan of their experiment are as follows: Cow manure in amounts varying from 1,000 to 4,000 pounds per acre is added to plots upon which in one series a nonlegume is growing and on the other series, a legume. The cow manure is plowed under with the accompanying green manure. This plan has been followed for several years. Crop yields and the amount of nitrogen in the crop are noted. From the fact that crop and nitrogen yields have been somewhat larger on those plots receiving the cow manure plus the green manure than on the ones receiving the green manure, they have concluded that the cow manure enhanced the rate of decomposition of the green manure. Also, those plots receiving the larger amounts of cow manure did not always give greater crop yields than those receiving the smaller. This, too, is interpreted as being indicative of an increase of the rate of decomposition of the green manure by the cow manure.

In 1916 Boltz (*1*) published the results of an interesting experiment with clover used as a green manure. Green clover at the rate of 7,744 pounds per acre was applied to two small areas, in one case merely put on the surface and in another spaded under. The clover and soil were analyzed for organic matter at the beginning of the experiment and the surface application of clover was collected at the end of the experiment and the amount of organic matter remaining was determined. The soil and soil and clover mixture were analyzed at the end of the experiment also. Throughout the course of the experiment, which ran from October 12 to May 5, 206 days, 66 per cent of the clover applied to the surface was lost, while 28.45 per cent of it was lost when it was incorporated with the soil. In a similar experiment, but carried out in a lysimeter and involving treatments of clover of 17,520 pounds per acre, 68.5 per cent of the organic matter of the clover was lost when applied to the surface and 58.5 per cent when spaded in with the soil. Only about 1 per cent of the organic matter of the clover was lost by drainage. The results obtained by Boltz are interesting when compared with those reported in this paper.

EXPERIMENT I

Part of the large sample of Miami silt loam soil that was used in the former experiments of this series (*7*, *8*) was used. Practically the same apparatus was used as formerly, the only difference being that, instead of putting the soil in pots under bell jars, it was placed in the ordinary

2.5-liter acid bottles. This diminished chances for leaks. The treatment of the soils, in tons per acre, was as follows:

Pot No.	Treatment.
1, 2.....	Control.
3, 4.....	3 tons of calcium carbonate.
5, 6.....	10 tons of manure.
7, 8.....	10 tons of manure and 3 tons of calcium carbonate.
9, 10.....	1 ton of oats.
11, 12....	1 ton of oats and 3 tons of calcium carbonate.
13, 14....	1 ton of oats and 10 tons of manure.
15, 16....	1 ton of oats, 10 tons of manure, and 3 tons of calcium carbonate.
17, 18....	1 ton of clover.
19, 20....	1 ton of clover and 3 tons of calcium carbonate.
21, 22....	1 ton of clover and 10 tons of manure.
23, 24....	1 ton of clover, 10 tons of manure, and 3 tons of calcium carbonate.

The manure used was well-rotted horse manure, air-dried and coarsely ground. The oats and clover were about two-thirds mature tops, air-dried and ground rather fine. The weights as given above refer to air-dried weights in all cases. Two and one-half pounds of soil were mixed with their respective treatments and then placed in the acid bottles. These were then connected with the apparatus which was freed from carbon dioxid. The soils were all made up to 22 per cent of moisture. This was done by adding 250 c. c. of "water" to each bottle. In every case 100 c. c. of this "water" were made up of an emulsion made from fresh soil; and, in the case of those soils receiving stable manure, 100 c. c. of fresh-manure emulsion were included in the 250 c. c. of "water." The soils, manures, and calcium carbonate were analyzed for total carbon at the beginning of the experiment. The experiment ran from July 10 to September 2, 1915, a total of 53 days.

At the end of the experiment all the soils were analyzed for carbonate carbon. Throughout the course of the experiment the carbon dioxid evolved was determined from time to time. In Table I will be found the total amount of carbon evolved from the soil as carbon dioxid, calculated in pounds per acre of 2,000,000 pounds. It will be observed that in general the duplicates agree very well. It may be stated that for each period the duplicates checked on the average about as closely as the summed-up amounts indicate. To put all the determinations which were made into a table would take up more space than we care to use here.

TABLE I.—*Amount of carbon evolved as carbon dioxid from soils in Experiment I*

[Results expressed as pounds of carbon per acre]

Soil No.	Original.	Duplicate.	Soil No.	Original.	Duplicate.
1, 2.....	771.9	767.7	13, 14.....	1,490.1	1,477.8
3, 4.....	1,392.5	1,393.3	15, 16.....	2,153.0	2,123.3
5, 6.....	1,070.1	1,071.8	17, 18.....	1,309.6	1,304.2
7, 8.....	1,625.5	1,625.5	19, 20.....	1,883.1	1,909.8
9, 10.....	1,153.8	1,223.0	21, 22.....	1,567.7	1,551.8
11, 12.....	1,794.1	1,802.3	23, 24.....	2,188.0	2,204.9

In Table II are found the number of pounds of carbon per acre given per day for the various periods. These were taken from the total carbon dioxid given off in the various periods. The data appearing in this table were used in plotting the curves of figures 1, 2, and 3.

TABLE II.—*Amount of carbon evolved as carbon dioxid per day from soils in Experiment I*

[Results expressed as pounds of carbon per acre per day]

Soil No.	Day.												
	1	2	3–4	5–8	9–11	12–15	16–18	19–22	23–25	26–32	33–39	40–46	47–53
1, 2.....	57.0	51.0	33.3	18.3	12.3	12.4	12.7	11.5	7.0	9.8	[a]13.6	13.1	10.6
3, 4.....	240.0	128.0	54.0	35.2	22.3	20.3	20.7	18.5	11.1	14.4	[a]21.0	17.1	12.5
5, 6.....	81.2	78.0	47.6	25.0	17.2	17.7	18.8	16.4	10.4	13.1	[a]19.4	14.0	16.4
7, 8.....	263.0	134.0	67.5	39.5	25.4	24.7	25.5	25.0	13.7	17.0	[a]24.2	[a]17.0	19.0
9, 10....	81.8	146.0	73.5	34.0	22.5	20.5	19.7	16.2	9.3	11.9	[b]13.0	14.1	14.6
11, 12...	283.0	196.0	97.5	49.5	32.9	29.5	27.8	23.9	14.0	16.7	[a]22.7	14.8	15.1
13, 14...	136.0	156.0	86.0	42.5	28.6	26.2	25.5	20.7	11.7	14.8	[a]21.2	15.4	14.4
15, 16...	317.8	196.0	121.0	57.2	38.7	35.2	34.0	29.7	17.7	20.8	[a]26.7	[2]14.0	19.7
17, 18...	6710	215.0	92.5	34.7	21.0	19.7	19.3	16.0	9.1	11.9	[a]20.4	13.5	12.4
19, 20...	200.0	307.0	119.0	49.5	31.4	28.5	28.1	23.6	14.2	16.8	[a]23.2	17.8	16.9
21, 22...	118.0	233.0	100.0	40.7	25.8	24.7	24.8	19.8	11.8	15.1	[a]22.4	15.0	15.8
23, 24...	273.0	284.0	126.0	55.5	36.7	34.7	33.3	30.1	17.9	21.6	[a]29.0	20.7	20.3

[a] Represents values for one soil, one determination having been lost.
[b] Represents values taken from average of preceding and succeeding determinations, both duplicates having been lost.

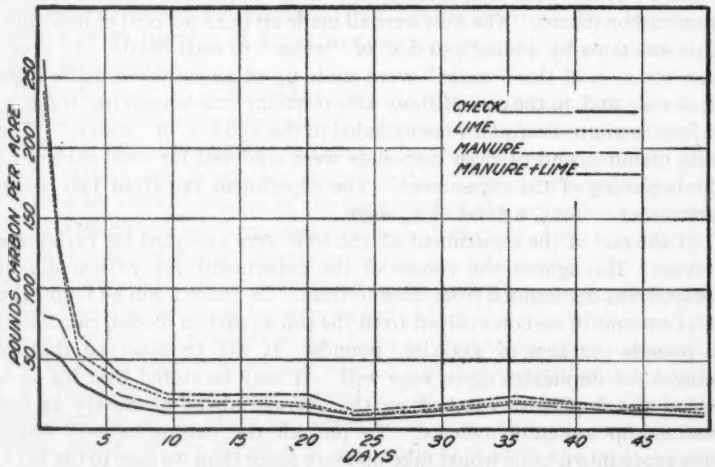


FIG. 1.—Graphs of the quantity of carbon evolved as carbon dioxid in the control, limed, manured, and manured and limed soils.

DISCUSSION OF THE CURVES

In figure 1 are given the curves for the carbon lost from the control, the limed, the manured, and the manured and limed soils. Throughout the course of the experiment it is seen that the limed soil is losing more carbon than the corresponding unlimed. It can not be said with certainty whether this is really due to an enhanced rate of decomposition

of the organic matter or whether it is simply due to a gradual liberation of the carbon dioxid of the calcium carbonate by relatively insoluble acids or by acids being gradually formed from organic matter.

Figure 2 shows the curves for the soils treated with oats alone and in the combinations with manure and lime. The noteworthy thing here is the slow initial rate of decomposition of the green manure and then its rapid decomposition followed by a slowing up of the process. Anticipating the results of the experiment which follows, we may say that probably the slow action at first was due to the dry condition of the oats. The slowing up of the process is due, no doubt, simply to the relative exhaustion of the more easily decomposed material in the added green manure.

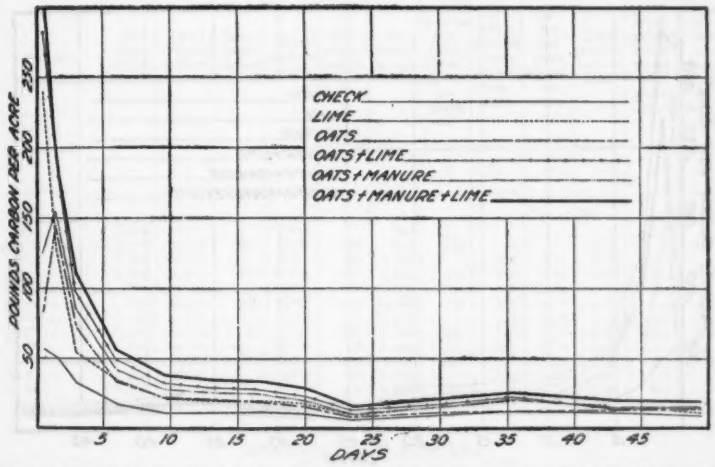


FIG. 2.—Graphs of the quantity of carbon evolved as carbon dioxid in soils treated with oats alone and in combination with manure and lime.

The curves for the green clover in its various combinations are shown in figure 3. In general the same may be said of these curves as of those for the oats. However, the clover decomposed much more rapidly than the oats in the early periods.

In Table III the summarized data for the whole experiment are given. An explanation of some of the columns of the table besides that appearing at the column head will probably make the table clearer. Unless otherwise indicated, all results are expressed in terms of pounds of carbon per acre of 2,000,000 pounds of soil. The figures in the second column were obtained from the analyses of the respective manure for total carbon. The values in the third column were found from the pounds of carbon in the soil originally and the added carbon. A sample of the air-dried calcium carbonate used was analyzed for carbon dioxid. From the amount obtained it was computed that the calcium carbonate was 94.42

per cent pure. Since practically no free alkali was found to be present, no doubt hygroscopic moisture made up the 5.58 per cent. Therefore the amount of carbon in the 3 tons of lime used per acre was 680 pounds, which number appears in the fourth column of the table. The figures in the next column were obtained directly from Table I. In the column headed "Inorganic carbon at end" are given the values obtained from the analysis of the soil for inorganic carbon by the MacIntire (5) method. These soils were analyzed while still moist, immediately after removal from the apparatus. No doubt the reason for finding inorganic carbon in the unlimed soil was that some carbon dioxid was retained in the soil moisture. No carbonates were found in the original air-dried soil. As is observed, only the averages of the duplicates are given. The greatest

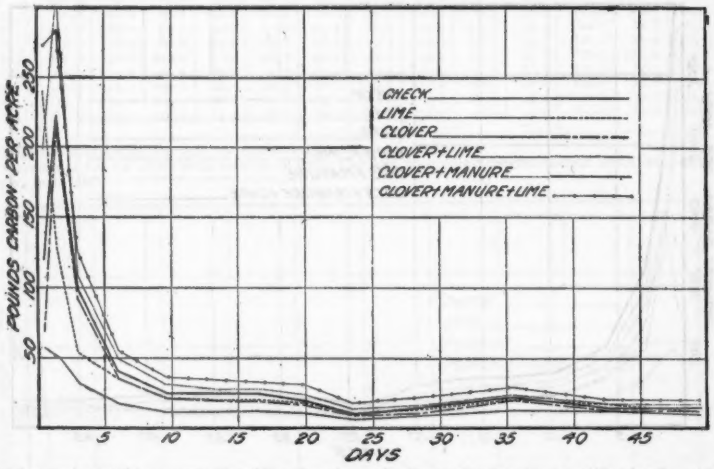


FIG. 3—Graphs of the quantity of carbon evolved as carbon dioxid in soils treated with green clover alone and in combination with manure and lime.

variation of the averages for the inorganic carbon in the unlimed soils was 2.5 pounds, while the greatest variation of the corresponding values for the limed soils was 5 pounds. This is thought to be a satisfactorily low experimental error. The weight of "Organic carbon lost" in the case of the unlimed soils were obtained simply by adding the total carbon lost to the inorganic found at the end of the experiment. For the limed soils, the following method was followed: The amount of inorganic carbon at the end of the experiment was subtracted from the amount added at the beginning. This, which is, of course, the number of pounds of inorganic carbon lost, was subtracted from the number of pounds of total carbon lost. This gives the desired figures listed in column 7. The next column is self-explanatory. In order to obtain the values found in column 9, it was assumed that in every case where organic matter was added to the soil the amount of carbon lost from the original

organic matter of the soil was the same as where no organic matter was added. Hence, the value found for soils number 5 and 6 in column 9 was obtained by subtracting the value for 1 and 2 from 5 and 6, in column 7. To obtain the number for 7 and 8 in column 9, the value for soils 3 and 4 was subtracted from 7 and 8 in column 7. Columns 10 and 11 are self-explanatory. To obtain the values found in column 12, it was assumed that where stable and green manure were used in the soil in combination the stable manure and soil organic matter lost as much carbon as where the stable manure alone was added to the soil.

TABLE III.—*Summarized data of Experiment I*

[Unless otherwise given, results are expressed as pounds of carbon per acre]

Soil No.	Organic carbon added.	Total organic carbon at start.	Inorganic carbon added.	Total carbon lost.	Inorganic carbon at end.	Organic carbon lost.	Excess organic carbon lost from limed over unlimed soil.	Organic carbon from added manure.	Carbon lost from added manure.	Total organic carbon lost.	Organic carbon from green manure alone.	Quantity of calcium carbonate at end in limed soils.
1	2	3	4	5	6	7	8	9	10	11	12	13
									Per ct.	*Per ct.*		*Lbs.*
1, 2	None.	29,513	.....	770	27	797	.....	.....	.....	2.70	.....	.....
3, 4	None.	29,513	680	1,393	218	931	134	.....	.....	3.15	.....	1,818
5, 6	7,500	37,013	.....	1,071	44	1,115	.....	318	4.23	3.02	.....	.....
7, 8	7,500	37,013	680	1,625	271	1,216	101	285	3.80	3.28	.....	2,260
9, 10	861	30,374	.....	1,188	31	1,219	.....	422	49.00	4.01	.....	.....
11, 12	861	30,374	680	1,798	270	1,388	169	457	53.10	4.57	.....	2,230
13, 14	8,361	37,874	.....	1,484	71	1,555	.....	758	9.07	4.10	440	.....
15, 16	8,361	37,874	680	2,138	283	1,741	186	810	9.70	5.10	525	2,360
17, 18	898	30,411	.....	1,306	36	1,342	.....	545	60.80	4.41	.....	.....
19, 20	898	30,411	680	1,896	274	1,490	148	559	62.30	4.89	.....	2,280
21, 22	8,398	37,911	.....	1,560	69	1,629	.....	832	9.91	4.29	515	.....
23, 24	8,398	37,911	680	2,196	310	1,826	197	895	10.70	4.82	610	2,580

DISCUSSION OF RESULTS

The number of pounds of organic carbon at the end of the experiment (shown in column 6 of Table III) are worthy of study. These results will be considered with those for the number of pounds of residual calcium carbonate. It is observed that in every case the organic manures acted as conservers of lime. As to why that is, it is difficult to understand. One would think that the acids formed by the decomposition of the manure would decompose the lime. Perhaps this takes place in the early stages, and then these calcium salts of the acids are in turn acted on by the microorganisms with the re-formation of calcium carbonate. In this connection the work of Gimingham (*2*) may be pertinent. He stated that the soil organisms changed the calcium salts of such organic acids as oxalic found in plant tissues to calcium carbonate. This can hardly account for all of the excess carbonate in the green-manured soils, as the following considerations will show. According to data appearing in Hopkins's Soil Fertility and Permanent Agriculture (*3, p. 603*) 1 ton

of young clover hay contains 34.2 pounds of calcium. If all of this were converted to calcium carbonate, it would give 85.5 pounds. The excess lime in the clover- and lime-treated soils over the soil receiving no treatment except lime is 460 pounds. Oat straw, according to the same authority, contains 6 pounds of calcium per ton; or in terms carbonate, 15 pounds. This accounts for only a small part of the excess carbonate in the oat-treated soils.

In a consideration of this question all the potential bases and acids in the manures should be considered, for after fairly complete decomposition the potassium, for instance, however originally combined with the organic material, would tend to combine either with an acid in the soil or with an acid from the organic material itself. This would relieve an equivalent amount of calcium carbonate from the necessity of having to neutralize acid.

Bearing directly upon this are the data found in Table IV, which is adapted directly from Hopkins (*3, p. 603*).

TABLE IV.—*Quantity (in pounds) of the elements in 1 ton of the clover hay and oat straw (dry material)*

Material.	Phosphorus.	Potassium.	Magnesium.	Calcium.	Sulphur.	Sodium.	Chlorin.
Oats	2.4	27.0	2.8	6.0	1.2	3.0	5.4
Calcium carbonate equivalent	7.7	34.6	11.7	15.0	3.7	6.5	7.6
Clover	9.0	50.6	9.4	34.2	1.4	2.8	6.6
Calcium carbonate equivalent	29.0	64.8	39.1	85.5	4.4	6.1	9.3

In Table IV are given the pounds of the elements in clover hay and oat straw found in 1 ton. It should be noted that the values are for oat straw and not the immature oat plant which was used in this experiment. No data could be found for such material. In the table the calcium carbonate equivalent of the various elements appear. These were calculated on the supposition that the elements would be completely hydrolyzed or oxidized to their respective bases or acids and would then neutralize an equivalent of acid, in the case of the base, or an equivalent of base, probably lime, in the case of the acids. For the oats the excess lime equivalent of the bases over the acids is 48.1 pounds, and for the clover 152.8 pounds. It should be noted that these numbers include in them the calcium carbonate equivalent of the calcium as mentioned above. This, then, does not account for all of the excess lime remaining in the green-manured soils, but it does, at least with the clover, account for an appreciable percentage of it. Therefore this excess lime must come from the calcium silicates, but this does not explain why there is a greater amount left in the manured than in the unmanured soils.

Next to be considered are the values found in columns 7 and 8 of Table III. It is seen that in every case the lime causes an increased decom-

position of organic matter. This of course has both a beneficial effect and a harmful effect from a practical standpoint. The greater rate of decomposition of the manure causes an increase in the rate of the making available of the plant food. It no doubt causes an increase in the rate of the destruction of possible toxic substances and probably in itself increases the air circulation in the soil. The harmful effect is the depletion of the organic matter in the soil, but since the main benefit derived from the organic matter of soil is its enhancement of microbial activity, anything within limits which aids in this activity is desirable.

Columns 9 and 10 (Table III) give the number of pounds of carbon lost from the added manure and the percentage loss, respectively. The most noteworthy thing in this connection is the large percentage of the green manure lost as compared with the stable manure. Thus, it is seen that 49 per cent of the carbon of the oats are lost, 60.8 per cent of that of the clover, and only 4.23 per cent of that of the manure. It seems surprising that about half of such an application of green manure would be lost in less than two months. It is believed that probably a somewhat comparable loss would take place in the field, because except for a lack of drainage these soils were held under conditions not greatly unlike those in the field. As to why, in the case of the stable manure in soils, a somewhat smaller amount of the manurial carbon was lost from the limed than the unlimed soils, we can not state. No doubt our assumption that the amount of carbon lost from the original soil organic matter in the manured soils is the same as that from the soil organic matter in the unmanured soils is not strictly true. As the manurial organic matter is more easily available, it is, no doubt, attacked largely at the expense of the soil organic matter. On the other hand, an enormous number, and doubtless a very great variety, of bacteria are introduced with the manure which of themselves serve to enhance the rate of decomposition of the organic matter and, hence, make a comparison of the manured, limed, and untreated soils of questionable significance. However, to arrive at some conclusion as to the amount of manure consumed in an experiment like this, some such an assumption must be taken. From column 11 (Table III) it is seen that in every case where total organic matter is considered, a larger percentage is decomposed from the limed than from the respective unlimed soil.

In column 12 (Table III) it is observed that the addition of stable manure has increased the rate of decomposition of the green manures to a small extent. According to some agriculturists, a dressing of stable manure on green manure before plowing under serves to enhance the rate of decomposition of the latter because of added bacteria. This experiment seems to confirm that belief. In anticipation of the consideration of the next experiment, it may be stated here that this result was not entirely confirmed when conditions were kept more typical of field practice.

CONCLUSIONS FROM EXPERIMENT I

(1) Lime in the form of a carbonate under the conditions of this experiment appreciably enhances the rate of decomposition of both original soil organic matter and the organic matter of stable manure and the green manures oats and clover when added to soil. Two of the more important results of this are the increased availability of plant food and the more rapid depletion of the soil organic matter. This latter effect would be partially and perhaps entirely offset by the fact that with lime larger crops could be grown which would give more organic matter to return to the soil.

(2) The green manures oats and clover under the conditions of this experiment are decomposed much more completely than stable manure. Clover is decomposed somewhat more rapidly than oats.

(3) Stable manure increases the rate of decomposition of green manure when used in connection with the latter.

(4) Both stable and green manures act as conservers of lime.

EXPERIMENT II

In the experiment just described it will be remembered that the stable and green manures were applied in dry and ground condition. It was thought that perhaps the reason that such a large percentage of oats and clover was decomposed and their carbon given off as carbon dioxid was because of their finely divided condition. Of course the reason for adding manures in such a state was to make sure that a composite sample was added in each case. To test this and other points, a similar experiment was planned, but with some of these objectionable features eliminated. The treatment of the soils, in tons per acre, is given in Table V.

TABLE V.—*Treatment of soils in Experiment II*

Pot No.	Air-dry basis.	Fresh basis.
1, 2.....	Control.....	Control.
3, 4.....	3 tons of lime.....	3 tons of lime.
5, 6.....	4.77 tons of stable manure.....	10 tons of stable manure.
7, 8.....	14.3 tons of stable manure.....	30 tons of stable manure.
9, 10.....	23.8 tons of stable manure.....	50 tons of stable manure.
11, 12...	4.77 tons of stable manure, 3 tons of lime.	10 tons of stable manure, 3 tons of lime.
13, 14...	14.3 tons of stable manure, 3 tons of lime.	30 tons of stable manure, 3 tons of lime.
15, 16...	23.8 tons of stable manure, 3 tons of lime.	50 tons of stable manure, 3 tons of lime.
17, 18...	4.77 tons of stable manure, 1.29 tons of oats.	10 tons of stable manure, 4 tons of oats.
19, 20...	4.77 tons of stable manure, 1.29 tons of oats, 3 tons of lime.	10 tons of stable manure, 4 tons of oats, 3 tons of lime.
21, 22...	4.77 tons of stable manure, 1.18 tons of clover.	10 tons of stable manure, 4 tons of clover.
23, 24...	4.77 tons of stable manure, 1.18 tons of clover, 3 tons of lime.	10 tons of stable manure, 4 tons of clover, 3 tons of lime.
25, 26...	1.29 tons of oats.....	4 tons of oats.
27, 28...	1.29 tons of oats, 3 tons of lime.....	4 tons of oats, 3 tons of lime.
29, 30...	1.18 tons of clover.....	4 tons of clover.
31, 32...	1.18 tons of clover, 3 tons of lime.....	4 tons of clover, 3 tons of lime.

The stable manure used was fresh horse manure, not dried. The oats and clover were taken from samples grown in the greenhouse to about two-thirds maturity. Material was cut into half-inch lengths and weighed out while still in an unwilted condition and thus added to the soil immediately. At the same time that the samples of manure were added to their respective soils, several samples of the green and stable manures were weighed into suitable containers and dried in the oven at 70° C. The weights were again taken, and from this the percentage of moisture in the samples as added was computed. The dried samples were finely ground and carbon determinations made on some of them. The results are given in Table VI.

TABLE VI.—*Composition of the manures used in Experiment II*

Material.	No.	Weight taken.	Dry weight.	Average.	Quantity of carbon in 0.5 gm.	Average.	Percentage of carbon.	Average.
		Gm.	*Gm.*		*Gm.*			
Oats	1	4.5	1.52		0.2152		43.04	
Do	2	4.5	1.39		.2110		42.20	
Do	3	4.5	1.36		.2329		46.58	
Do	4	4.5	1.45		.2098	0.2172	41.96	43.45
Do	5	4.5	1.49					
Do	6	4.5	1.51	1.454				
Clover	1	4.5	1.32		.2281		45.62	
Do	2	4.5	1.32		.2346		46.92	
Do	3	4.5	1.30		.2184		43.68	
Do	4	4.5	1.31		.2243	.2263	44.86	45.26
Do	5	4.5	1.31					
Do	6	4.5	1.37	1.322				
Stable manure	1	11.3	5.3		.1930		38.60	
Do	2	11.3	5.6		.1952		39.04	
Do	3	11.3	5.6		.1936	.1939	38.72	38.7
Do	4	11.3	5.35	5.39				

An examination of the results in Table VI shows with what degree of uniformity in composition the samples of manures were as they were added to the soil. The experiment was started and carried through in all respects as the previous experiment.

In Table VII will be found the results for the total amount of carbon given off as carbon dioxid. Owing to breakage, the alkali from the alkali towers of pots 17, 19, and 30, ran over into their respective soils and spoiled them early in the experiment. Large molds appeared in pots 13 and 15 after several weeks, which accounts for the missing determination of those soils. A mold also appeared in No. 16, which was removed as soon as discovered. Since its duplicate had already been discarded, the values for the carbon dioxid of No. 16 were taken from the values found for the soils treated with the same amount of manure but without lime. It is of course realized that this does not have much justification, and, hence, the values for No. 16 should not be depended upon for any definite conclusion.

TABLE VII.—*Total carbon evolved as carbon dioxid from soils in Experiment II*

[Results expressed as pounds of carbon per acre]

Soil No.	Original.	Duplicate.	Soil No.	Original.	Duplicate.
1, 2	1,686	1,722	18	4,239	.....
3, 4	2,710	2,744	20	5,082	.....
5, 6	3,658	3,636	21, 22	4,195	4,242
7, 8	8,211	8,206	23, 24	5,077	4,989
9, 10	12,483	12,050	25, 26	2,657	2,704
11, 12	4,289	4,357	27, 28	3,215	3,407
14	8,769	.....	29	2,688	.....
16	12,703	.....	31, 32	3,245	3,274

In Table VIII appear the average amounts of carbon evolved as carbon dioxid per day in the successive periods. From this table the curves appearing in figures 4 to 9 were drawn.

TABLE VIII.—*Quantity of carbon evolved as carbon dioxid per acre per day in soils of Experiment II*

[Results expressed as pounds per acre]

Soil No.	1st day.	2d day.	3d day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.	11–12 day.	13–14 day.	15–16 days.	17–19 days.	20–22 days.
1, 2	78.5	87.7	46.4	58.1	43.3	34.1	29.9	30.4	26.7	25.0	25.0	15.3	15.9	20.0	14.6
3, 4	277.0	146.0	73.4	90.6	81.8	57.3	50.7	50.7	43.1	38.4	37.0	26.4	21.4	29.0	22.7
5, 6	120.0	137.0	91.7	160.0	129.0	120.0	126.0	113.0	104.0	86.7	88.5	56.5	42.2	49.7	40.0
7, 8	221.0	210.0	202.0	307.0	294.0	247.0	232.0	208.0	200.0	187.0	178.0	120.0	116.0	127.0	95.0
9, 10	328.0	312.0	303.0	468.0	412.0	338.0	305.0	289.0	260.0	262.0	239.0	169.0	137.0	177.0	121.0
11, 12	336.0	156.0	135.0	178.0	175.0	149.0	147.0	122.0	119.0	107.0	97.0	65.9	54.0	53.0	44.0
13, 14	445.0	256.0	256.0	408.0	383.0	266.0	282.0	265.0	208.0	186.0	193.0	126.0	103.0	129.0	90.3
15, 16	476.0	345.0	335.0	562.0	433.0	375.0	374.0	338.0	292.0	272.0	237.0	164.0	173.0	152.0	136.0
18	216.0	197.0	181.0	232.0	203.0	149.0	143.0	137.0	124.0	114.0	101.0	64.0	57.5	58.0	42.3
20	374.0	216.0	197.0	264.0	206.0	204.0	180.0	145.0	148.0	141.0	122.0	100.0	65.5	63.0	47.7
21, 22	192.0	174.0	191.0	266.0	186.0	159.0	149.0	158.0	120.0	108.0	103.0	63.5	52.5	54.0	38.7
23, 24	373.0	202.0	202.0	288.0	275.0	184.0	182.0	195.0	141.0	122.0	113.0	71.0	58.0	59.3	43.3
25, 26	156.0	157.0	125.0	136.0	108.0	72.2	63.2	63.1	51.7	44.6	45.3	30.3	28.3	34.7	32.7
27, 28	325.0	189.0	152.0	152.0	135.0	88.4	91.8	78.1	67.4	68.7	[a]60.0	34.2	30.8	38.7	17.6
29	149.0	124.0	127.0	184.0	122.0	85.0	72.5	59.4	53.9	42.6	42.2	23.1	22.7	27.2	18.0
31, 32	322.0	159.0	177.0	187.0	126.0	105.0	87.6	80.9	77.9	58.9	55.0	37.2	33.3	33.3	24.0

Soil No.	23–26 days.	27–29 days.	30–33 days.	34–36 days.	37–44 days.	45–51 days.	52–58 days.	59–65 days.	66–72 days.	73–79 days.	80–86 days.	87–93 days.	94–100 days.	101–107 days.	108–114 days.
1, 2	10.8	8.1	12.0	8.4	6.4	7.9	5.0	5.1	4.6	4.3	4.0	4.5	4.7	4.6	3.6
3, 4	14.6	11.1	17.6	14.2	9.3	12.0	7.3	6.4	6.6	5.1	5.3	6.4	6.3	6.7	5.2
5, 6	23.1	20.4	29.8	22.2	16.9	19.0	12.3	11.5	9.3	10.6	9.7	7.7	8.5	9.4	7.4
7, 8	62.0	4.8	72.2	54.3	37.6	48.6	37.6	25.7	31.4	25.1	23.0	23.3	22.0	21.9	16.6
9, 10	86.0	76.3	105.0	84.3	73.5	97.8	76.4	81.4	61.3	39.9	35.0	33.6	32.3	32.4	24.3
11, 12	26.0	18.8	30.0	20.7	14.7	20.6	13.1	11.1	12.3	9.1	8.7	10.6	9.4	9.6	6.4
13, 14	68.0	59.7	73.2	82.0	54.6	56.1	33.6	[a]23.0	[a]19.7	[a]18.6	[a]17.0	[a]20.8	[a]15.8	[a]17.6	[a]10.9
15, 16	96.0	65.7	115.0	61.7	75.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18	26.0	20.2	40.3	20.5	14.4	17.0	16.7	9.1	9.2	8.6	8.6	8.6	9.3	8.7	7.1
20	27.7	23.7	42.7	23.9	18.1	18.9	12.7	9.6	10.9	9.8	8.7	11.2	10.1	9.1	8.1
21, 22	25.5	20.4	28.7	19.9	14.0	18.0	10.4	9.4	9.4	8.4	7.9	9.2	8.9	8.7	7.4
23, 24	27.0	20.6	42.5	22.5	17.6	22.0	12.5	9.7	11.6	9.2	7.7	10.3	10.1	9.9	7.8
25, 26	14.8	10.3	17.0	11.8	8.8	9.8	6.4	4.9	6.8	5.4	5.6	5.1	5.6	5.5	4.1
27, 28	11.8	14.1	24.1	17.8	[a]11.4	13.1	7.9	7.3	7.5	6.6	5.9	7.7	9.3	7.3	4.5
29	12.1	9.5	29.5	18.2	18.2	9.1	12.6	8.6	8.4	5.9	7.6	4.5	5.0	5.0	4.5
31, 32	19.1	14.8	19.2	16.2	9.2	18.6	6.5	9.3	6.9	6.7	7.2	8.6	4.7	7.9	5.3

TABLE VIII.—*Quantity of carbon evolved as carbon dioxid per acre per day in soils of Experiment II*—Continued

Soil No.	115–121 days.	122–128 days.	129–135 days.	136–142 days.	143–149 days.	150–156 days.	157–163 days.	164–170 days.	171–178 days.	179–185 days.	186–192 days.	193–199 days.	200–209 days.	210–216 days.
1, 2	2.3	3.0	3.3	3.0	2.7	1.9	3.4	2.8	5.3	[a] 6.4	7.8	14.1	6.3	4.8
3, 4	5.0	4.0	4.2	3.5	3.9	2.8	4.5	4.0	6.1	13.9	9.3	16.4	14.7	6.6
5, 6	4.9	6.0	6.0	5.0	4.6	3.9	7.0	5.7	8.9	[a] 23.8	3.3	[a] 3.9	5.9	12.0
7, 8	10.2	12.9	13.6	10.5	10.3	7.1	12.1	9.3	16.2	[a] 16.6	14.7	[a] 19.4	14.8	12.7
9, 10	14.1	18.0	17.7	13.7	13.4	9.7	15.6	12.6	21.2	[a] 26.9	4.7	13.2	17.5	13.5
11, 12	6.1	6.3	6.1	4.9	5.4	4.2	5.8	5.4	8.8	[a] 7.1	9.3	3.9	13.0	10.5
13, 14	[a] 7.6	[a] 9.3	[a] 8.1	[a] 12.2	[a] 8.9	[a] 5.1	[a] 9.9	[a] 8.8	[a] 12.2	[a] 13.6	[a] 14.0	[b] 14.4	[a] 15.0	[a] 12.0
15, 16	14.1	10.9	16.3	11.9	11.5	8.2	12.7	11.7	17.0	18.3	23.3	13.5	15.5	12.7
18	4.4	5.5	5.8	4.6	4.7	3.5	5.5	4.5	8.4	8.5	11.0	[b] 9.5	7.8	5.9
20	5.0	6.6	6.2	5.3	4.9	3.9	7.2	6.3	8.4	10.7	13.4	[b] 12.0	10.6	8.7
21, 22	4.5	5.7	5.8	4.7	4.7	3.8	6.2	4.5	8.7	7.9	8.8	[a] 8.5	8.8	6.6
23, 24	4.5	6.5	6.7	6.3	4.9	4.1	7.4	6.8	9.2	10.7	10.0	[a] 10.7	10.1	7.3
25, 26	2.9	3.2	3.7	2.7	3.2	2.0	3.8	2.6	6.0	9.2	10.0	14.8	10.9	11.4
27, 28	3.2	5.2	5.5	3.1	4.5	3.2	4.5	4.5	6.9	[a] 5.9	7.0	13.7	[a] 8.4	7.0
29	2.7	3.7	3.7	3.1	2.9	2.4	3.8	3.3	6.1	6.0	6.8	5.9	7.0	4.5
31, 32	3.6	4.7	4.9	3.8	3.5	2.7	5.9	4.5	6.8	8.4	6.3	[a] 10.0	8.9	10.2

[a] Represents value for one soil, one determination having been lost.
[b] Represents values taken from the average of preceding and succeeding determinations, both duplicates having been lost.

DISCUSSION OF THE CURVES

In figures 4 and 5 appear the curves for the soils receiving the various amounts of stable manure used alone and in combination with lime. The control and limed soils are also shown. Special attention is called to the manner of construction of the curves in the two different figures. In these two and the succeeding figures different standards have been used which are thought to bring out the important points to advantage. These changes can be followed easily by watching the notation on each figure. All of the curves are seen to be well above the curves for the control soil. With the exception of a few isolated points, the curves for the limed soils are well above those for their respective unlimed soils. The fact that the limed soils almost invariably gave off more carbon dioxid than their respective unlimed duplicates, even toward the end of the experiment, which ran more than half a year, shows that there must be greater bacterial activity induced by the lime. Of course it might be said that the excess carbon dioxid came from the lime itself, but it will be shown in Table IX that less lime was used in the manured than in the unmanured soils. This precludes that explanation of the fact. Also it would seem that after such an extended length of time all of the soil acid would be neutralized, so that the most reasonable conclusion is as stated above—namely, that lime increases bacterial activity to a marked extent.

When compared to the curves for the manure in the former experiment, it is seen that the manure curve is well above that where dry, well-rotted manure was used, in spite of the fact that in the case of the dry manure much more organic matter was present than in the case of the wet manure. As shown in Table VI, the 11.3 gm. of wet manure

representing an application of 10 tons per acre, was only equivalent to 5.39 gm., or slightly less than 5 tons per acre. The reason for this is no doubt due to several causes. One of these is that many more bacteria were added with the fresh manure, and the second is that drying resulted in precipitation of considerable soluble organic matter in such a form that it redissolved rather slowly in the soil moisture, and drying also rendered the solid organic matter more impervious to moisture and,

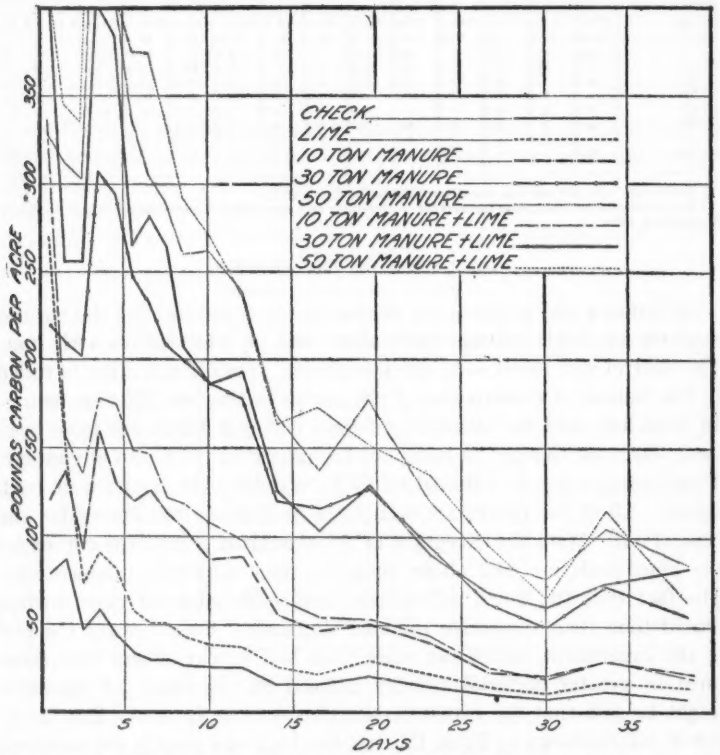


FIG. 4.—Graphs of the quantity of carbon evolved as carbon dioxid in soils receiving various amounts of manure used alone and in combination with lime. Period, 1–39 days.

hence, to bacterial action. Perhaps the main reason is that the easily available organic matter of the well-rotted manure had all been decomposed.

On comparing for the moment the curves in figures 6 and 7 with the curves for the similarly treated soils of the former experiment, shown in figure 2, it is seen that in the latter case where the fresh undried green manure was used, the rate of decomposition at first was enormously greater. Therefore the grinding had no effect on the green

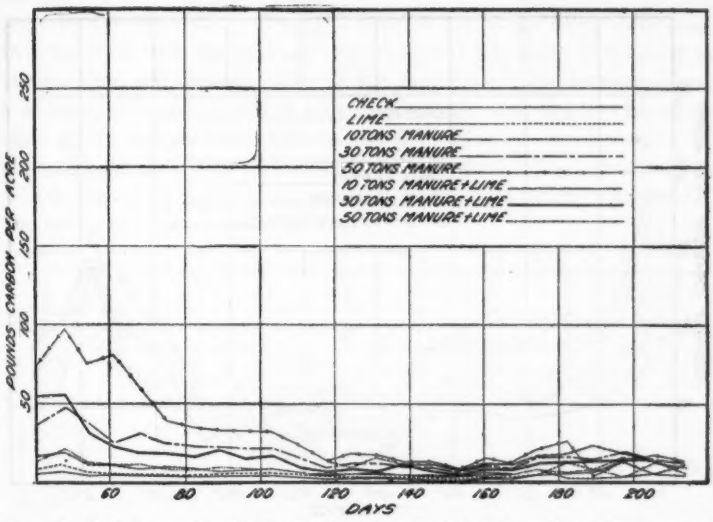


FIG. 5.—Graphs of the quantity of carbon evolved as carbon dioxid in soils receiving various amounts of manure used alone and in combination with lime. Period, 40–216 days.

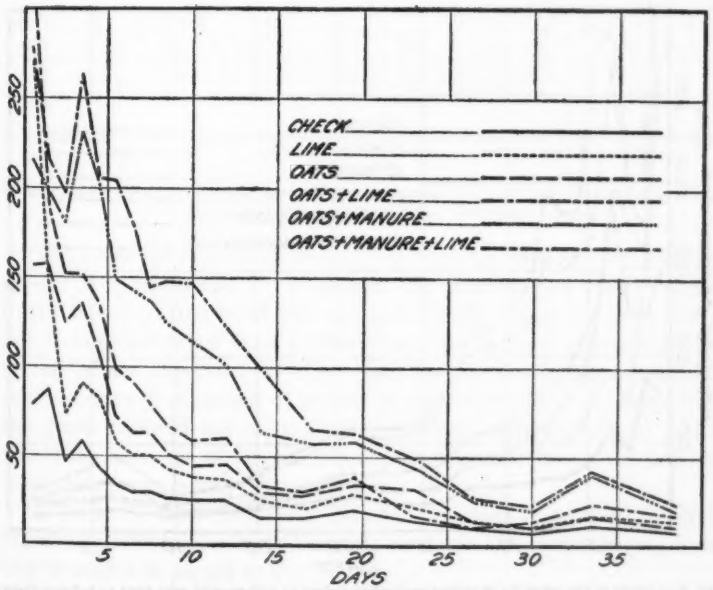


FIG. 6.—Graphs of the quantity of carbon evolved as carbon in soils treated with lime and oats alone and in combination with manure and lime. Period, 1–39 days.

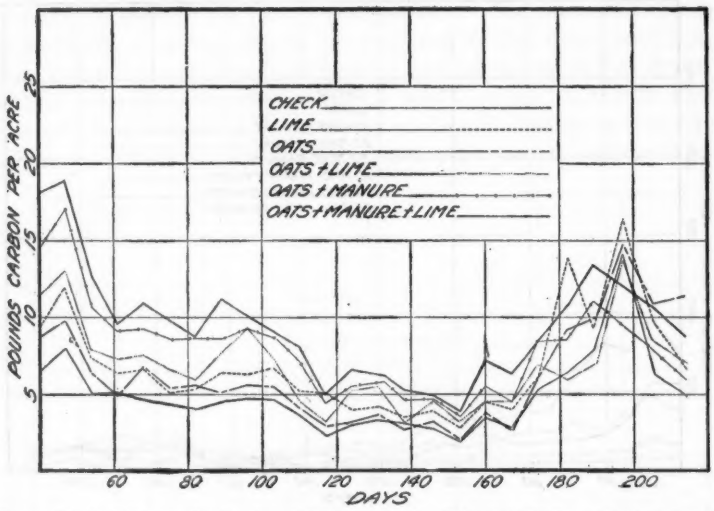


FIG. 7.—Graphs of the quantity of carbon evolved as carbon in soils treated with lime and oats alone and in combination with manure and lime. Period, 40–216 days.

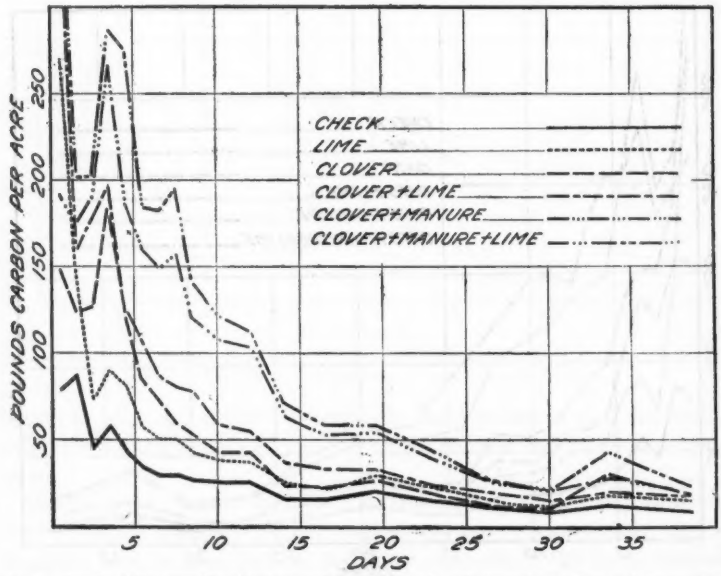


FIG. 8.—Graphs of the quantity of carbon evolved as carbon in soils treated with lime and clover alone and in combination with manure and lime. Period, 1–39 days.

manure, as was thought at first. Or, if it did, it was more than overcome by the effect of the drying. Another important thing to be noted in connection with the curves in figures 6 and 7 is that, after about the one-hundred-and-twentieth day of the experiment, the amount of carbon being given off from the soils treated with the oats was about the same as the control soil. This means that most of the carbon of the green manure has been decomposed and evolved. The same may be said in regard to soil treated with lime and oats when compared to the soil treated with lime only.

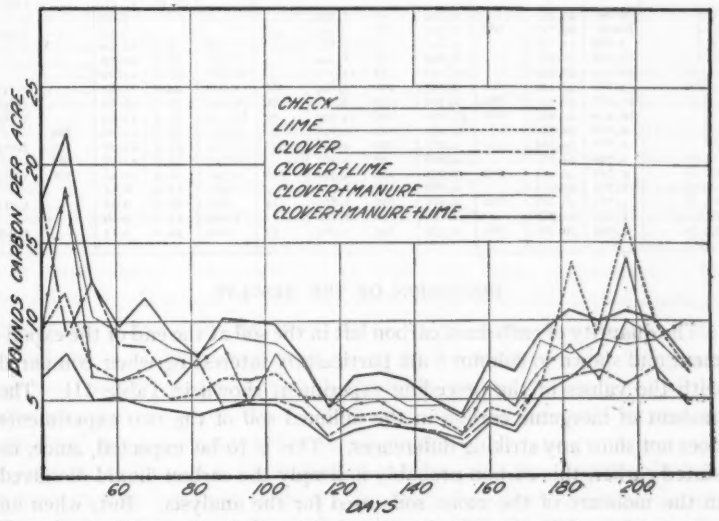


FIG 9.—Graphs of the quantity of carbon evolved as carbon in soils treated with lime and clover alone and in combination with manure and lime. Period, 40–216 days.

The curves for the clover-treated soil, with its various combinations, appear in figures 8 and 9. In general the same may be said in regard to the clover-treated as of the oat-treated soils. Here the fresh material decomposed much more rapidly than the dried and ground material of the former experiments. Also after the one-hundred-and-twentieth day, the rate of evolution of carbon as carbon dioxid is the same from the green-manured soil as the corresponding ungreen-manured. It is seen that here, as in the former experiment, the clover decomposed somewhat more rapidly than the oats.

In Table IX the summarized data for the whole experiment is given. Since this table is constructed exactly as Table III, no further explanation is needed in regard to it.

TABLE IX.—*Summarized results of Experiment II*

Soil No.	Organic carbon added.	Total organic carbon at start.	Inorganic carbon added.	Total carbon lost.	Inorganic carbon at end.	Organic carbon lost.	Excess organic carbon lost from limed over unlimed soil.	Organic carbon lost from added manure.	Carbon lost from added manure.	Total organic carbon lost.	Organic carbon from green manure alone.	Quantity of calcium carbonate at end in limed soils.
1	2	3	4	5	6	7	8	9	10	11	12	13
									P. ct.	*P. ct.*		*Lbs.*
1, 2	None.	29,513	.....	1,704	46	1,750	.....	.....	.....	5.92	.....	.....
3, 4	None.	29,513	680	2,727	182	2,229	479	.....	.....	7.55	.....	1,516
5, 6	3,686	33,199	.....	3,647	36	3,683	.....	1,933	52.4	11.10	.....	.....
7, 8	11,058	40,571	.....	8,208	34	8,242	.....	6,492	58.8	20.70	.....	.....
9, 10	18,430	47,943	.....	12,267	55	12,322	.....	10,632	57.7	25.80	.....	.....
11, 12	3,686	33,199	680	4,323	206	3,849	166	1,620	44.0	11.60	.....	1,715
14	11,058	40,571	680	8,709	242	8,321	79	6,092	55.1	20.80	.....	2,020
16	18,430	47,943	680	12,703	226	12,249	73	10,020	54.4	25.60	.....	1,885
18	4,801	34,314	.....	4,239	53	4,292	.....	2,542	52.5	12.50	609	.....
20	4,801	34,314	680	5,088	230	4,638	343	2,409	50.2	13.50	779	1,915
21, 22	4,740	34,253	.....	4,218	47	4,265	.....	2,515	52.8	12.50	582	.....
23, 24	4,740	34,253	680	5,033	218	4,571	306	2,342	49.4	13.40	722	1,815
25, 26	1,115	30,628	.....	2,680	55	2,735	.....	980	78.9	8.93	.....	.....
27, 28	1,115	30,628	680	3,310	230	2,860	125	631	56.6	9.34	.....	1,915
29	1,054	30,567	.....	2,688	62	2,750	.....	1,000	95.0	9.00	.....	.....
31, 32	1,054	30,567	680	3,259	204	2,783	33	554	52.6	9.11	.....	1,700

DISCUSSION OF THE RESULTS

The quantity of carbonate carbon left in the soil at the end of the experiment and shown in column 6 are particularly interesting when compared with the values of the preceding experiment shown in Table III. The amount of inorganic carbon in the unlimed soil of the two experiments does not show any striking differences. This is to be expected, since, as stated earlier, this carbon probably is simply the carbon dioxid dissolved in the moisture of the moist soils used for the analysis. But, when an examination of the results for the limed soil is made, consistency is observed. In the experiment which ran for 216 days, 182 pounds of carbon remained, while 218 pounds were left in the experiment which ran only 53 days. Thus, in the time from the fifty-third day to the two-hundred-and-sixteenth day 36 pounds of carbon were lost. In terms of calcium carbonate this represents 300 pounds. With the 10-pound manure treatment there were 455 pounds of calcium carbonate decomposed from the fifty-third to the two-hundred-and-sixteenth day. However, not too much significance should be placed on this figure because of the different character and amount of the manure used. In the case of the oats the difference is 335 pounds of carbonate. For the clover the difference is 480 pounds. Somewhat more significance can be placed on these figures although no absolute dependence, for the green manures were in quite different states when added to the soils.

Here, as in the former experiment, the manures act as conservers of lime. A discussion of this question is given in connection with the first experiment. The oats seem to use less of the lime than the clover.

It is seen that in every case except where the soils were treated with 50 tons of manure the lime enhanced the rate of decomposition of the organic matter. As already mentioned, the soil treated with 50 tons of manure and lime developed a mold, which was later removed. Therefore, not much dependence should be placed on the results for that soil. The figures as a whole given in column 8 are not very consistent. The excess carbon from the soils treated with both stable manure and green manure is greater than where the similar amounts of manure were used separately. Yet, where no manure was used, the excess carbon was greater than in any other case. It seems that the original organic matter in a soil needs lime for its decomposition, while the organic matter of manures used here does not need lime.

The values given in columns 9 and 10 are extremely interesting. On considering the percentage of carbon lost from the various manures, it is seen that more than half of the carbon of the stable manures has been evolved in the course of the experiment. Thus, more than 10 times as much of the manure in this experiment has been decomposed as in the earlier experiment reported in this paper. This is a far greater difference than can be accounted for by a consideration of the time the two experiments ran—namely, 53 and 216 days, respectively. It should be recalled that in the first experiment dry, well-rotted manure was used, whereas in the latter fresh, moist manure was used. As stated above, in the discussion of the curves the reasons for this difference are that the physical condition of the fresh manure was in favor of its more rapid decomposition, more bacteria were added with it, and it contained more easily available organic matter.

Another noteworthy circumstance is that with the limed soils less organic carbon has been evolved than from the corresponding unlimed soil. Here, again the only explanation seems to be that the organic matter of the manures does not need lime for its decomposition. Possibly the lime, together with the organic matter, causes such a high percentage of carbon dioxid in the soil atmosphere and soil solution that it becomes slightly toxic to the bacteria. Our apparatus was of such a nature that cultivation of the soil during the course of the experiment was not feasible. Possibly with cultivation, which would have tended to diminish the concentration of carbon dioxid, the results would have been different. Particularly to be noticed is the very large percentage of the green manures which were decomposed. There were evolved as carbon dioxid 78.9 per cent of the carbon of the oats and 95 per cent of that of the clover. It should be recalled that the respective figures for the experiment which ran 53 days were 52.4 per cent and 62.3 per cent. Therefore it seems that the physical condition of the green manures did not greatly influence the rate of decomposition. While the manner of application of the oats and clover in this last experiment—

that is, in pieces not over ½ inch in length—can not be said to represent conditions exactly comparable to field practice, yet it is believed that the rate of decomposition would have been approximately the same if they had been added in larger pieces. The results found here confirm those of Boltz already referred to. What shall we say, therefore, concerning the use of green manures in building up the organic matter of the soil? In the first place, it is to be remembered that neither in our experiments nor in those of others have the roots of the plants been used. Parts of the roots would probably decompose somewhat more slowly because of their toughness. However, it is doubtful if this would radically change the results. As Pieters (*6*) concludes from his review of the subject, the use of green manures generally gives greater crop yields to crops immediately following. This increase of crop would usually, if properly handled, give greater crop residues to plow under, which in turn would tend to enrich the soil. Then it must not be forgotten that the green manure would of itself add available plant food to the soil, taken partly or largely from the unavailable supply. And, of course, in the case of leguminous green manures, nitrogen would be added also. Then its decomposition would render an additional amount of plant food available.

In practice it is often observed that, where insufficient time is allowed between the plowing under of the green manure and the planting of a crop, in a dry season the crop suffers from lack of moisture. This probably is due to the turning under of the green manure in large bunches. From the results of this experiment it is seen that if some practical plan could be found to mix the material thoroughly with the soil, most of it would be decomposed in a short time. This must be left, of course, to field experiments.

When results for total organic matter are considered, it is observed from column 11 (Table IX) that the limed soils showed a greater percentage of decomposition than the unlimed. In some instances, however, the differences are so small as not to be significant.

In the twelfth column (Table IX) the carbon coming from the green manure alone is shown. In the case of the unlimed soils, it is less by nearly one-half than the corresponding amount from the green manure applied to the soil alone. From the limed soils, however, it is seen that the stable manure apparently quite appreciably increases the rate of decomposition of green manures. We are not prepared to give an explanation of these facts. However, we believe that the results of this experiment and the one preceding warrant the conclusion that green manures under most conditions will be decomposed sufficiently rapidly in the soil without the addition of stable manure.

CONCLUSIONS FROM EXPERIMENT II

The conclusions to be drawn from Experiment II are as follows: It is, of course, understood that it is not proposed that they hold for all soils under all conditions. However, it is believed that some generalizations are possible.

(1) Soil organic matter decomposes more rapidly under limed than under unlimed conditions.

(2) When organic matter in the form of stable manure and the green manures oats and clover is added to the soil, the total organic matter—that is, the organic matter of the soil plus the added organic matter—decomposes more rapidly under the influence of lime than without it. When the added organic matter alone is considered the rate of decomposition is lessened by the lime.

(3) The carbon of stable manures is evolved as carbon dioxid from soil under unlimed conditions to the extent of approximately 55 per cent. The carbon of oats under like conditions is evolved to the extent of 79 per cent and that of clover 95 per cent. Under unlimed conditions the amount of stable-manure carbon evolved is only slightly less than under limed conditions, while only about 57 per cent of the carbon of oats and 53 per cent of the carbon of clover is given off under limed conditions.

(4) All the manures tended to conserve the lime.

(5) Under unlimed conditions stable manure did not increase the rate of decomposition of the green manure as measured by the evolution of the carbon dioxid. With lime there was a slight increase in the amount of carbon given from the green manure when used with the stable manure over that given by the green manure when the latter was used alone. It should be recalled that in the former experiment stable manure enhanced the rate of decomposition of the green manure only to a slight extent.

(6) There is not a very great difference in the rate of decomposition of the green manure when added in a finely ground, dry state and when used fresh and in a relatively coarse state of subdivision.

LITERATURE CITED

(1) BOLTZ, G. E.
1916. LOSS OF ORGANIC MATTER IN GREEN MANURING. *In* Ohio Agr. Exp. Sta. Mo. Bul., v. 1, no. 11, p. 347–350.

(2) GIMINGHAM, C. T.
1911. THE FORMATION OF CALCIUM CARBONATE IN THE SOIL BY BACTERIA. *In* Jour. Agr. Sci., v. 4, pt. 2, p. 145–149.

(3) HOPKINS, C. G.
1910. SOIL FERTILITY AND PERMANENT AGRICULTURE. 653 p., illus., pl., maps. New York.

(4) LIPMAN, J. G., et al.
1913–16. THE INFLUENCE OF BACTERIA IN MANURE ON THE DECOMPOSITION OF GREEN MANURE (LEGUME AND NON-LEGUME). *In* N. J. Agr. Exp. Sta., 33d–36th Ann. Rpt., [1911]/12–[1914]/15.

(5) MacIntire, W. H., and Willis, L. G.
1913. SOIL CARBONATES, A NEW METHOD OF DETERMINATION. Tenn. Agr. Exp. Sta. Bul. 100, p. 83–97, 1 fig. References, p. 97.

(6) Pieters, A. J.
1917. GREEN MANURING: A REVIEW OF THE AMERICAN EXPERIMENT STATION LITERATURE. *In* Jour. Amer. Soc. Agron., v. 9, no. 2, p. 62–82; no. 3, p. 109–126; no. 4, p. 162–190. Bibliography, p. 173–190.

(7) Potter, R. S., and Snyder, R. S.
1916. CARBON AND NITROGEN CHANGES IN SOIL VARIOUSLY TREATED: SOIL TREATED WITH LIME, AMMONIUM SULPHATE, AND SODIUM NITRATE. *In* Soil Science, v. 1, no. 1, p. 76–94, 2 fig. Literature cited, p. 93–94.

(8) ——— ———
1917. CARBON DIOXIDE PRODUCTION IN SOILS AND CARBON AND NITROGEN CHANGES IN SOILS VARIOUSLY TREATED. Iowa Agr. Exp. Sta. Research Bul. 39, p. 255–309. 21 fig. Bibliography, p. 306–309.

EUPATORIUM URTICAEFOLIUM AS A POISONOUS PLANT

By C. DWIGHT MARSH, *Physiologist in Charge*, and A. B. CLAWSON, *Physiologist, Poisonous Plant Investigations, Pathological Division, Bureau of Animal Industry, United States Department of Agriculture.*

INTRODUCTION

Among the suggested causes for the disease popularly known as milk sickness, trembles, slows, tires, etc., has been the plant commonly called white snakeroot (*Eupatorium urticaefolium*, the *Eupatorium ageratoides* of the older literature). Arguments have been advanced *in extenso* both for and against this theory. In later years the possibility of the connection of this plant with the disease has lessened since Crawford (*4*) [1] in 1908 published his negative pharmacological work and Jordan and Harris (7) in 1909 published their paper on the *Bacterium lactimorbi*. While there have still been authors who clung to the white snakeroot origin of the disease, it has been rather generally believed that the real cause was not a plant poison but more likely a disease-producing germ. Although the investigation of the subject has been carried on by the Department of Agriculture for some years, little attention has been paid to the question of the connection of this plant with the disease, as it was thought probable that it should be disregarded.

In the fall of 1914 there were some cases of milk sickness near Beecher City, Ill., and the attending physician, Dr. E. R. Brooks, made some experiments with the *E. urticaefolium* which led him to think it to be connected with the disease. At his solicitation a representative of the department visited the neighborhood, and arrangements were made to conduct a series of feeding experiments with a view to determine, if possible, whether or not the plant produced the disease. The experiments were carried on during the fall and winter of 1914 and 1915 at Washington and during the fall of 1915 near Beecher City. The material used in the first season was collected by Dr. Brooks and shipped to Washington, where it was fed both in fresh and dried condition. All the material used in the fall of 1915 was fed fresh from the immediate neighborhood of the experiment.

The general results of the experiments in their relation to the disease of milk sickness are not in form for publication, but it has been clearly demonstrated that *E. urticaefolium* must be counted as one of the rather important stock-poisoning plants, which produces serious losses of domestic animals. On this account it seems wise to publish the results so far

[1] Reference is made by number (italic) to "Literature cited," p. 714.

Journal of Agricultural Research, Washington, D. C. Vol. XI, No. 13 Dec. 24, 1917 Key No. A—33

as they relate to *E. urticaefolium* as a poisonous plant, with the hope that some of the losses may be avoided; for it is evident that while in many localities this plant is suspected to be the cause of milk sickness, its importance as a stock-poisoning plant has received little recognition.

DESCRIPTION OF THE PLANT

Eupatorium urticaefolium Reichard (Pl. 52) quoted as *E. ageratoides* L. in the older botanies, is a slender, erect, perennial herb, belonging to the family Compositae. Its leaves, which are 3 to 5 inches long, are opposite, broadly ovate, pointed, sharply toothed and thin, and have rather long petioles. The stems are viscid-villous. The small white flowers are in compound corymbs of 8 to 30 flowers, appearing in the late summer and fall. The plants are from 1 to 4 feet in height.

It is found widely distributed in the eastern United States and as far west as Minnesota, Oklahoma, Nebraska, and Louisiana. Its favorite habitat is in rich, damp woods. It is abundant in the groves along the watercourses of the Middle States, and grows with special profusion in the so-called coves, or damp, shaded ravines, of the north slopes of the southern Appalachians. It is by no means, however, confined to shaded situations, for it sometimes grows in masses on cleared hillsides in the open.

It is commonly known as white snakeroot. Other names which have been applied to it are white sanicle, Indian sanicle, deerwort, bone set, poolwort, poolroot, richweed, squawweed, whitetop, and steria.

The root has been used in medicine as a diuretic and antispasmodic.

The common thoroughwort, *Eupatorium perfoliatum* L., which grows in similar localities, but usually on soils with more moisture, is readily distinguished from *E. urticaefolium*, as it is a coarser plant and the leaves are long, narrow, rugose, and, as the name indicates, are without petioles and are united around the stem.

EXPERIMENTAL WORK

In the experimental work of 1914 three head of cattle and two head of sheep were used. Following is the detail of the experiments.

CALF 668.—This animal was a bull calf, born in March, 1914, and kept during the summer in a pasture on the department farm at Arlington, Va. It was brought into the barn for experimental feeding October 7. It was in good condition and weighed 340 pounds.

The plants fed to this animal were shipped from Beecher City, Ill., and consisted of stems, leaves, and flowers, which were fed in as fresh a condition as possible, but had lost some moisture, so that the weights of material fed probably represented a somewhat larger quantity of the strictly fresh plant.

The animal received and ate the plants as follows: October 8, 4.5 pounds; October 10, 9.5 pounds; October 12, 7 pounds; and October 14,

7 pounds. He received, all told, on the basis of 1,000 pounds of animal weight, 82.4 pounds of *E. urticaefolium*, a daily ration of 11.8 pounds, during the time he was eating. During this time he was also fed hay in quantities not weighed on October 9, 13, 14, and 15. No symptoms of poisoning were shown until October 15. On this day the animal was depressed and constipated. He lay down much of the time, and sometimes refused to rise. He ate very little of the hay. On the 16th his condition was unchanged. On the 17th he could get up, but would do so only with considerable urging. He showed no desire to eat either hay or green grass. He was taken out of the pen, and after being led around a little, trembled violently and lay down. It was difficult to make him get up and return to the pen. On October 18 and 19 he grew gradually weaker. He could get upon his feet, but trembled violently when standing. The respiration was rapid. He ate nothing except a few handfuls of grass and a very little grain.

He died on the morning of October 20 without any struggle. Death occurred on the sixth day after the last feeding of *E. urticaefolium*. Observations upon the temperature during the illness showed nothing abnormal.

In the autopsy, petechiæ and hemorrhagic spots were found on the heart, both on the auricles and ventricles and also on the aorta and *vena cava*. The walls of the duodenum, jejunum, and ileum were congested, and there were homorrhagic spots on the cecum. The liver was light in color, possibly somewhat degenerated. There was nothing else abnormal.

BULL 663.—This animal, a bull, was brought in for feeding October 7, 1914, He had been in pasture on the Arlington farm since the preceding March and was in good condition, weighing 692 pounds.

The plants used for this animal had been shipped in from Beecher City, and autoclaved at a pressure of 7 pounds in order to destroy any possible germs of disease. This sterilized material was fed as follows: October 8, 5.2 pounds; October 10, 10.5 pounds; October 12, 26 pounds; October 14, 29 pounds; October 15, 15 pounds; making a total in 8 days of 85.7 pounds. On the basis of 1,000 pounds of animal weight, this would have been 123.8 pounds of *E. urticaefolium*, an average daily ration of 15.45 pounds per 1,000 pounds of animal weight. Hay was given on October 13 and 15 and on the days following. No symptoms were noted until October 15; then the animal exhibited constipation and a loss of appetite. On the 17th when he was led about, the exercise caused more or less labored breathing and there was some trembling of the muscles of the flanks, hips, and muzzle. On the 19th he was somewhat worse; he had little appetite, showed a disinclination to stand, and exhibited the same muscular trembling as on the 17th. On October 20, while still disinclined to stand, he, on the whole, showed improvement, and after this

gained steadily. On the 23d he was returned to the pasture and seemed to be recovered from his indisposition. His temperature was normal during the experiment.

This bull received a second feeding of *E. urticaefolium* from January 7 to 21, 1915. This was of dried material which was ground up and mixed with grain. In the 15 days of the experiment he ate 103 pounds of this material. It was found by tests that the plant loses in drying 65 per cent, so that he ate an equivalent of 294.3 pounds of fresh plant. As the animal at this time weighed 760 pounds, this amounted to 387.2 pounds of *E. urticaefolium* per 1,000 pounds of animal weight, and the average daily ration on this basis was 25.8 pounds.

When this experiment was begun, the animal was very active. On October 15 he was rather dull, and on January 20 and 21 he was decidedly depressed and exhibited slight trembling. There were no further symptoms. The temperature remained normal during the experiment.

Cow 122.—This was a Jersey cow, 4 years old, that had been used as a milch cow during the preceding summer. She had been tested in the fall for tuberculosis and gave a positive reaction. At the time of the experiment she weighed 785 pounds.

From December 15, 1914, to January 8, 1915, she was fed on *E. urticaefolium* that had been collected and dried at Beecher City. This was fed with hay and grain. She received a total of 96 pounds, which would be equivalent to 274.3 pounds of fresh plant. On the basis of 1,000 pounds of animal weight, this cow received a total of 394.4 pounds, or an average daily ration of 14.1 pounds.

Except for some constipation in the early days of the experiment, there were no ill effects from the feeding. Her temperature remained normal during the experiment and she weighed 790 pounds on January 7.

SHEEP 308.—A female spring lamb, weighing 80 pounds, was given *E. urticaefolium* from Beecher City on October 24, 26, and 28, 1914. None of that given on the 28th was eaten, and the total quantity eaten on the other days was 5 pounds. The animal was fed hay on October 25 and was later given what grain she would eat. The total quantity eaten was equivalent to 6.25 pounds per hundredweight of animal. In the forenoon of October 26 she exhibited a lack of appetite, eating nothing, and some mucus was running from the nose. At 3.30 p. m. she showed marked depression and was standing humped up, with the head held low, and brownish green material running from the mouth. When led about, she began to stagger and tremble, the trembling appearing first in the shoulders. When left alone, she lay down. In the forenoon of October 29 she was found lying on the left side with legs extended. She was raised, but could not stand alone. She remained in this condition, growing gradually weaker through the 30th and died between 2 and 4 a. m. on October 31.

Her temperature was normal during the experiment, except that it was rather high on October 30. In the autopsy the only positive abnormal condition was a congested duodenum.

SHEEP 309.—This was a female spring lamb weighing 84 pounds. She was fed upon autoclaved *E. urticaefolium*. This was given October 24 and 26, 1914, and the uneaten material was removed on the 29th. She ate in this time 4 pounds, or 4.4 pounds per hundredweight of animal. There was no effect from this feeding.

On November 2 she was given autoclaved material, the feeding being given by the balling gun. When she had received 1.38 pounds she commenced to salivate, and the feeding was terminated. She frothed at the mouth, was nauseated, and her breath had a bad odor. On November 3 she showed a lack of appetite and preferred to lie down. When led about, she walked unwillingly, showed marked trembling, and soon lay down. Plate 53, A, shows the weakness of the animal, and Plate 53, B, while apparently a poor picture, shows by the indistinctness of the sheep as compared with other objects the continuous trembling to which the animal was subject when on its feet. On November 4 the symptoms were more marked. When led about, she trembled violently and soon fell. This was repeated several times. The respiration and pulse were very rapid when attempts at movement were made. The temperature was 104.2° F. This condition continued through November 5, the temperature varying from 104.8 to 105.4. In the forenoon of the 6th the temperature was 105.8, and the respiration was labored and noisy. The animal was unable to stand, and there were occasional convulsive movements of the body muscles. She died at 4.30 p. m., and an autopsy was made on the morning of November 7. Nothing abnormal was found except possible congestion of the duodenum and small intestine and a similar condition of the liver and kidneys.

SHEEP 310.—This was a ewe about 6 months old, weighing 66 pounds. January 29, 1915, dried plants of *E. urticaefolium* ground to a powder and mixed with water were fed with a balling gun, 1.75 pounds being used. This was equivalent to 7.6 pounds of green material per 100 pounds of animal. It produced no bad effect.

On February 9 another feeding of 3 pounds of similar material was made in the same way. This was an equivalent of 13.82 pounds of green material per 100 pounds of animal. It, too, produced no effect besides evidence of discomfort from the large feeding. As will appear in the general discussion, the failure to produce intoxication was probably due to the fact that the plant in drying loses much of its toxicity.

COW 699.—This animal, which was fed at Fancher, Ill., in the fall of 1915, was an old milch cow, estimated to weigh 1,000 pounds. She was in good condition, giving a good flow of milk. She was fed from September 21 to 30 on fresh material of *E. urticaefolium*, including stems, leaves, and flowers; this was mixed with grass and bran. She received

during this time 106 pounds of *E. urticaefolium*, 138 pounds of grass, and 11.5 pounds of bran, an average daily ration of 10.6 pounds of Eupatorium, 12.5 pounds of grass, and 1 pound of bran. The material was kept before her constantly in the attempt to make her eat as much as possible. She did not take kindly to the *E. urticaefolium*, and it was necessary to keep mixing fresh grass with it. A calf (No. 700) was allowed to take all her milk.

On September 30 it was evident that she was losing in activity and that her flow of milk was much reduced. She moved slowly and after a little exercise trembled noticeably in the shoulders, hips, and thighs. On October 1 she was much constipated and strained when defecating. She ate no *E. urticaefolium* and even refused to pick grass out of the mixture. On October 2 she was lying down and unable to get on her feet. Grass was offered to her, and she tried to eat it. The nose and lower jaw trembled violently. After attempting to rise, she went over on her side, with marked trembling about her head. Her flow of milk had nearly stopped. On October 8, in the morning, she was found dead.

Her temperature during the experiment was rather low, but hardly subnormal. At the autopsy the liver was somewhat yellowish, the duodenum was slightly congested, and the ileum showed many patches of congestion. Nothing else abnormal was noticed.

CALF 700.—This was a male calf which on September 21 was only 2 or 3 days old. He was put with cow 699 and took all her milk supply. He showed no ill effects from the milk, but suffered from lack of nourishment as the cow began to dry up.

From October 4 to 9 he was fed with *E. urticaefolium* by the balling gun, receiving a total of 5.6 pounds. This would be equivalent to 56 pounds for a 1,000-pound animal, or an average daily ration of 9.3 pounds for six days. During this time he was fed on skimmed milk. He showed nausea on October 8, and on the 9th this was accompanied by vomiting, with loss of appetite. On October 7 and 8 he shivered at times, but this may have been due to insufficient food rather than to any toxic effect of the *E. urticaefolium*. He was killed and autopsied on October 10. The result of the autopsy was entirely negative.

SHEEP 367.—This sheep, a yearling ewe weighing 60 pounds, was fed at Fancher, Ill., from September 22 to 28, inclusive, on fresh plants of *E. urticaefolium*. She ate 1.1 pounds on September 22, and on the remaining days, except September 24, she was given the material by a balling gun, receiving all told 4.3 pounds, or on the basis of 7.1 pounds per 100 pounds of animal, an average daily ration of 1 pound.

In the afternoon of September 25, after having received the plant at the rate of 3.8 pounds per 100 pounds animal weight, the sheep appeared inactive, preferring to lie down. On September 26 it was thought that she trembled some after being exercised, and there was some trembling of the jaw when she was being fed with the balling gun. On September

27 she was constipated; no further evidence of trembling. On September 28 she trembled after exercise in the morning, and the lower jaw trembled when she was being fed with the balling gun. She grew weaker during the day, lay down most of the time, ate very little, and trembled when on her feet. From September 29 to October 1 her condition continued much the same as on September 28, with gradually increasing weakness until on October 1 she was unable to rise or even to remain in an upright position, and lay on her side during the day. Plate 54 shows the condition of the animal. The urine and feces were bloody. She was found dead on the morning of October 2. There had been almost a complete loss of appetite, so that she had eaten very little during the experiment and weighed after death only 43 pounds.

The records of temperature, pulse, and respiration showed nothing unusual except a rather high pulse rate. The autopsy showed nothing distinctly abnormal, except that the liver had a spotted appearance and was possibly somewhat degenerated.

SHEEP 368.—This was a ewe about 4 years old, weighing 100 pounds. She was fed at Fancher, Ill., from September 22 to 24, 1915, with the balling gun, receiving a total of 5 pounds, an average daily ration of 1.7 pounds. She became nauseated during the feeding on September 23, but showed no further symptoms at that time. While being fed in the morning of the 24th some trembling of the nose was noted and the animal preferred to lie down. A little later the trembling and weakness became more marked, increasing until she was unable to stand and went over upon her side, salivating and vomiting. Plate 55 shows her condition at this time. She died at 1.30 p. m., having lost 12 pounds during the experiment. Her temperature remained normal during the experiment. In the autopsy the only marked change was in the liver, which presented a mottled appearance.

SHEEP 369.—This animal was a yearling ewe weighing 63 pounds. She was given *E. urticaefolium* with the balling gun, at Fancher, Ill., from October 3 to 7, 1915. She received 0.22 pound on October 3, and on the following days received four feedings of 0.22 pound each, thus getting all told 3.7 pounds. On the basis of an animal of 100 pounds this would be 5.9 pounds, or an average daily ration of 1.2 pounds.

While she was being fed in the afternoon of October 5, after about 1.5 pounds of the plant had been eaten, there was some trembling of the head. At the end of the first feeding on October 6 there was trembling of the jaw; at this time about 2.2 pounds had been eaten. There were no other symptoms until the morning of the 8th. When first seen on that day, she was lying down, and when made to rise walked a little way and lay down. The respiratory movements were deep and jerky, and she lay with the eyes half closed, grunting with each expiration. A little later when made to rise she stood humped up and moved about uneasily. The forelegs began to tremble, the trembling increasing in violence for

about five minutes, when she lay down. She gradually grew weaker, exhibiting a repetition of the same symptoms. On the morning of October 10 she could still stand for a few minutes. She was killed at 9 a. m. on that day, and an autopsy was made. The autopsy showed nothing that could be considered abnormal. The records of temperature, pulse, and respiration showed nothing that could be considered specifically abnormal.

LETHAL DOSE

The experiments were too few in number to make it possible to speak positively in regard to the lethal dose. The results, however, are significant.

SHEEP.—Excluding No. 310, which was fed on the dry plant, considering No. 369 as a case of death, for this animal would have died, without doubt, and adding the amounts of the two feedings of No. 309 for reasons which will appear later, the average lethal dose was 6.05 pounds per hundredweight of animal, with a minimum of 5 pounds and a maximum of 7.1 pounds. The variation from the average is so little that it is probably safe to say that the lethal dose for sheep is about 6 per cent of the animal's weight.

CATTLE.—For the cattle the average lethal dose of the two fatal cases, Nos. 668 and 699, is 94.2 pounds per 1,000 pounds of animal. If it can be assumed that these are average cases, it would appear that the lethal dose for cattle is about 10 per cent of the animal's weight. Cattle apparently are somewhat less susceptible to the poison than sheep.

TOXIC DOSE

The experiments with the sheep failed to show any difference between the lethal and toxic doses.

In the case of the cattle, No. 699 showed symptoms on 82.6 pounds per 1,000 pounds of animal, and succumbed after 106 pounds, and No. 663 showed symptoms after 123.8 pounds of autoclaved material. No. 700 exhibited symptoms after 56 pounds, but in this case there was a complication because of the animal's weakness from lack of food. It appears then that the margin between the toxic and lethal limits is quite narrow.

EUPATORIUM POISONING CUMULATIVE

While there was some evidence that the toxic dose was smaller when the material was given in a short time, this difference was comparatively slight. It appears from the experimental cases that the elimination of the toxic substance takes place very slowly, so that there is a distinct cumulative effect. This was evident both in the cattle and in the sheep. This may explain the fact that sheep 309 was killed in a forced feeding of only 1.6 pounds per hundredweight on November 2, 1914. From October 24 to 26 it had received 4.4 pounds with no symptoms. The

combined feeding of the two periods was 6 pounds, the quantity which appears to be the average toxic or lethal dose; and if it is assumed that the toxic substance of the first period had not been eliminated the fatal effect of the small forced feeding may be explained.

SYMPTOMS

The most noticeable symptom and perhaps the most typical is trembling, which is seen especially in the muscles about the nose and in those of the legs. This becomes marked after exercise, and may be violent, ending in the animal falling to the ground.

In some cases trembling is the first symptom noted, but in others there is a preceding period of marked depression and inactivity.

In most cases the animals are constipated, and some have bloody feces.

Generally when fed intensively the animals are nauseated, and this is sometimes accompanied with vomiting.

The respiration is normal, except that during exertion it is quickened and somewhat labored.

In the average of cases there were no significant changes in temperature. In one or two cases it was slightly lower than normal, and in others somewhat higher than normal, during the latter part of the illness.

Weakness is very pronounced. The animals have difficulty in standing and sometimes remain down for a prolonged period before death. Sometimes they live for several days after the appearance of the first symptoms.

AUTOPSY FINDINGS

Generally speaking, there was more or less congestion in the duodenum and ileum. The liver in most cases showed evidence of a pathological condition, presenting the appearance of "nutmeg liver." Except in the liver and intestine, there was no evident abnormal condition.

PATHOLOGY

Microscopic examinations have been made of various tissue from animals poisoned by *E. urticaefolium*. Two organs, the liver and kidney, show pathological changes of a significant nature.

LIVER.—The livers from those animals which were autopsied shortly after death in all cases showed a condition of fatty infiltration, and most of them showed congestion, either acute or subacute. The fat globules were formed within the cells, in some cases occupying nearly the entire cell body. The globules were variable in size. They were least numerous in the case of calf 700 and most marked in the case of cow 669. It is to be noted that cattle 669 died from the effect of the plant, while calf 700 did not show positive symptoms.

Of the sheep, No. 368 showed very marked congestion, the cells of the lobules, more particularly near the *vena centralis*, being pushed far apart, giving the appearance of nutmeg liver. In cases Nos. 367, 368, and 369

the fat globules were more noticeable on the peripheral cells of each lobule. Sheep 369 showed pronounced necrosis of the cells in certain areas. In sheep 367 the liver had apparently been congested, as the cells about the *vena centralis* were pushed apart.

KIDNEY.—The kidney sections from all animals examined were very similar in pathological appearance. The lumina of the tubules, more particularly those near the periphery, and including the convoluted tubules and the loop of Henle, contained a serous exudate, showing that congestion had existed. There were few normal cells remaining, most of them having begun to break down, the portion of the cells next the lumen having sloughed off, leaving the edge irregular and ragged. The remains of such cells could often be seen in the lumina. Most of the blood vessels excepting the capillaries were well filled with blood, which, taken with the serous exudate in the lumina of the tubules, indicates a subacute stage of congestion. In the case of cow 699 the capillaries as well as other blood vessels were distended with blood. The condition of degenerated epithelial cells would suggest the presence of some irritating substance.

While certain pathological conditions were found in the lung tissue of some of the cases, they were not constant enough to be considered significant.

ANIMALS SUSCEPTIBLE TO EUPATORIUM POISONING

The writers' experiments were with cattle and sheep. Definite feeding experiments have been made by others, as will be shown later, which prove the toxicity of the plant for horses, and extracts have poisoned cats, dogs, and guinea pigs. So far as reported experimentation goes it appears that no animals are immune to the toxic principle of the plant.

In regard to man, the definite evidence is hardly conclusive, in spite of a number of instances in which the plant or an extract is said to have been poisonous. Some of these cases are clearly apochryphal. But on the whole there seems to be little doubt that human beings may be poisoned by the plant if a sufficient dosage is used.

COMPARATIVE TOXICITY OF GREEN AND DRY PLANT

The dry plant was fed by the balling gun to sheep 310 on January 29 and February 9, the animal receiving the equivalent of 7.6 pounds of green plant per hundredweight on the first date and 13.82 pounds on the second. The first feeding was more than the average toxic dose of the fresh plant and the second feeding more than twice that amount, but there was no evidence of poisoning in either case.

Two head of cattle were fed on dry material, No. 122 receiving the equivalent of 274.3 pounds of green plant per 1,000 pounds with no effect, while No. 663 received the equivalent of 294.3 pounds with only slight symptoms. This latter amount was nearly three times the esti-

mated toxic dose of the fresh plant. It seems that without doubt the plant loses a large part of its toxicity in drying.

ARE THE MILK AND FLESH OF POISONED ANIMALS POISONOUS?

Milk from cow 122, during the period in which she was eating *E. urticaefolium*, was fed to cat 3 and dog 15. It should be noted in this connection that cow 122 received dry material and showed no symptoms of poisoning. While it is generally stated that "milk-sick" cows show no symptoms while giving milk, it is evident not only from the experiments of the Department of Agriculture but from the testimony of others that cows even when giving milk can show symptoms of Eupatorium poisoning.

Cat 3 was an old animal. He drank the milk for about a week and then refused it, and some time later died. There was no evidence that the milk injured it, and its death was due to old age.

Dog 15 was fed milk from the same cow from December 20 to December 31 with no deleterious effect.

Meat from cattle 668 and sheep 309, both animals having died from Eupatorium poisoning, was fed to dog 11 from October 23 to November 16. During this time the dog ate over 60 pounds of meat, or an average of about 2.4 pounds a day. As he weighed only 15 pounds, he ate 4 times his weight of meat. He was in poor condition at the conclusion of the experiment, and died some days later. There were no definite symptoms, and probably the death was not due to *E. urticaefolium*. It must be recognized, however, that it is possible that the plant had some injurious effect.

Dog 12, weighing about 10 pounds, was fed like dog 11 from October 23 to November 16 on the meat from cattle 668 and sheep 309, eating 18.9 pounds, without any effect.

Dog 21, an old shepherd dog, was put in a pen with the meat from cattle 699, which had died of Eupatorium poisoning. He ate very little, and later the meat was cooked and fed to him from October 5 to 9, 1915, during which time he ate 6½ pounds. He refused to eat more, and was killed and autopsied on October 10. His lack of appetite was doubtless due to his age. The result of the feeding and of the autopsy was entirely negative.

During the time of the experiment with dog 21 two or three hounds from a neighboring farm broke into the pen where the meat was kept and practically cleaned up the skeleton. None of the dogs were known to be poisoned.

While the experiments with the flesh of poisoned animals can not be considered conclusive, everything points to the probability of the harmlessness of the meat.

In this connection it may be noted that Mr. George Walker, of Andrews, North Carolina, a region where trembles in cattle is common, has called attention to the fact that during the Civil War both armies, when in

that neighborhood, took all the animals they could get, and, under the circumstances, the owners did not take pains to point out the animals affected with trembles, although doubtless many such were used, and yet there were, so far as known, no bad results.

BACTERIA NOT THE CAUSE OF ILLNESS IN ANIMALS FED WITH EUPATORIUM URTICAEFOLIUM

Cultures were made from the blood of bull 663 and calf 668 and from the milk of cow 122. In connection with the feeding experiments with cow 699 and calf 700 and sheep 368 and 369, cultures were made from the skin, liver, spleen, feces, and milk. From these cultures were isolated the individual organisms, where any were found. Out of all these cultures two of the bacteria bore some resemblance to the *Bacterium lactimorbi* of Jordan and Harris, but it seemed reasonably certain both from the morphological and cultural characters that they were not identical with it. The one that showed the most resemblance to *Bact. lactimorbi* was inoculated into dogs with no results. It should be noted, too, that bull 663 showed toxic symptoms of illness from autoclaved material, and sheep 309 was killed on plants treated in that manner.

These experiments, while not sufficient in number for positive proof, make it probable that it is a toxic substance in the plant which causes the illness, and not the presence of pathogenic bacteria.

RELATIONSHIP BETWEEN POISONING BY EUPATORIUM URTICAEFOLIUM AND MILK SICKNESS

There is no question that *E. urticaefolium* is poisonous and produces a line of symptoms closely resembling those said to be typical of milk sickness in cattle and other animals. Most of the so-called milk-sick cases in cattle occur in localities where *E. urticaefolium* grows. Field cases seen by the writers have the same symptoms as those which have been observed in experimental animals and have been diagnosed as intoxication by *E. urticaefolium*. There seems little doubt that many if not most cases of milk sickness or trembles in cattle are caused by this plant. It does not follow, however, that all cases of milk sickness are produced by *E. urticaefolium*.

Somewhat extended bacteriological investigations by the writers of this paper, the results of which will be reserved for another paper, appear to substantiate the claim of Jordan and Harris that there is a bacterium widely disseminated in the soil and on plants, which, under certain conditions—conditions for the most part unknown—produces a disease in man and animals, in which symptoms are exhibited which appear to be those of milk sickness.

Very much more work is necessary in order to clear up the subject, and definite plans have been made for extended work to this end; but it seems highly probable at this stage of the investigation that under

the terms "milk sickness" or "trembles" are included at least two distinct things, one the poisoning of animals by *E. urticaefolium*, and the other a bacterial disease to which both animals and men are susceptible.

Although the question of the differential diagnosis of the two diseases will be discussed in detail in the report of the bacteriological investigations, it may be noted here that trembling appears to be more distinctly characteristic of Eupatorium poisoning, and that a subnormal temperature is one of the diagnostic symptoms of the bacterial diseases, while poisoning by *E. urticaefolium* produces no distinct effect on the temperature.

CONDITIONS UNDER WHICH ANIMALS MAY BE POISONED

It is known that stock may be pastured where *E. urticaefolium* is abundant, and that the use of these pastures may be continued for years with no harm. Most of the cases of poisoning occur in the late summer and fall and generally in years when there is a deficiency of moisture and a consequent shortage of forage grasses. Cases also occur when grazing animals are confined to a limited area on which the plant is abundant. The experimental work shows that *E. urticaefolium* is not palatable to our domestic animals and that they will avoid it in the presence of other foods. As in the case of most stock-poisoning plants, there is a direct relation between shortage of food and cases of poisoning, although, of course, sporadic cases may occur under other conditions.

REMEDIES

Sick animals should be treated with remedies to relieve the constipation and increase elimination. To this end purgatives may be used, of which perhaps Epsom salts is the best. This should be used in doses of 1 pound for a 1,000-pound animal. The feed should be laxative, like bran, oil meal, etc. In parts of North Carolina it is customary to feed milk-sick animals with green corn and pumpkins, and there is good reason to consider this a desirable diet.

Inasmuch as the toxic substance of the plant is eliminated very slowly, quick recovery must not be expected, and the animals should be given somewhat prolonged attention.

PREVENTION

In many places milk-sick areas have been fenced off with consequent prevention of losses. In some localities where *E. urticaefolium* is particularly abundant this evidently is advisable. The clearing of land and seeding to corn, grain, or grasses will of course stop the trouble. It has long been known that trembles affects animals pastured on unbroken land and that the disease disappears after cultivation.

So far as getting rid of the plant is concerned, however, it must be remembered that partial clearing is not sufficient. It is true that the

plant favors damp, shaded places, but it sometimes grows most luxuriantly on partially cleared land. It has been noticed in the mountains of North Carolina that the plant increases enormously on cleared land, and only disappears after the land has been seeded down.

If the poisonous character of the plant is recognized, much can be accomplished by so handling the animals that they do not graze largely in areas where *E. urticaefolium* is abundant.

PREVIOUS EXPERIMENTAL WORK ON EUPATORIUM URTICAEFOLIUM

The results of the experimental work undertaken by the writers were so definite and convincing that it seemed best to reexamine the literature of milk sickness with reference to the results obtained by other authors. Although the literature is very extensive and *E. urticaefolium* has long been suspected as a possible cause of the disease, the published statements in regard to the plant are not very numerous.

Apparently the first published statement in regard to the effect of *E. urticaefolium* was by Rowe (*14*) in the Ohio State Journal of September 6, 1839. He made a public experiment of feeding "the weed" on the farm of Francis Asbury, and published a statement by Mr. Asbury with affidavits by four other men. "The weed" was fed to a cow for seven days, together with common feed. A 3-months-old calf took the milk of the cow during that time, exhibited symptoms of trembles on the sixth day, and died on the ninth. A yearling steer at the same time was fed with "the weed" and other necessary feed, had the trembles, and died at the end of seven days. It is stated in the report of the Ohio State board of agriculture for 1858 (*9*) that the weed used was *Eupatorium ageratoides*.

A statement that *E. urticaefolium* (*ageratoides*) may be the cause of milk sickness was made by Barbee (*1*) in 1840. He says that Dr. Owen told him that he had produced trembles in a calf by an extract of the plant. Barbee himself gave a decoction to a dog and produced "shaking palsy," vomiting, and death in three hours.

Drake in 1841 (*7, p. 215–216*) tells of two specific cases in which cattle were turned into pastures covered with *E. ageratoides* without any bad results.

Dewey in 1854 (*6*), thinks the cause of the disease is a

> succulent plant, which grows in damp and thickly shaded bottoms, and bears a white blossom until late in the autumn.

Probably the plant thus described is *E. urticaefolium*. He states that he knows all the symptoms of the disease were produced in calves by experimental feeding of this plant.

In the Thirteenth Annual Report of the Ohio State Board of Agriculture (*9*), printed in 1859, is an unsigned article, probably written by Townshend, in which is a letter from W. J. Vermilya. Vermilya in 1855 put 200 sheep in a field containing *E. ageratoides*, saw them eat

the plant, and lost 8 lambs that had developed the trembles. In 1856 he fed the plant to a mare, beginning the feeding on October 12. Symptoms of trembles were very pronounced on October 21, and on the 23d the animal died. During the illness the animal was examined by three doctors, two farriers, and other citizens, and all agreed that the mare had the trembles.

William Jerry, of Madison County, Ill., in 1867 published in the Missouri Republican a statement which was reprinted in the Medical and Surgical Reporter of Philadelphia (*13*), that he had been made violently ill with symptoms of milk sickness by eating *E. ageratoides* prepared as greens. He also produced sickness in a dog by a decoction of the plant. Sawyer in the same number of the magazine says that he has experimental evidence that the plant will produce in animals a disease very similar to milk sickness.

Moseley in 1906, in a detailed article (*10*), in which he states positively that *E. ageratoides* is the cause of trembles in animals and of milk sickness in man, relates may cases of poisoning of animals by the plant in Ohio pastures, and gives details of his own successful experiments with the plant and with extracts, using as experimental animals cats, dogs, rabbits, and sheep.

Crawford in 1908 (*4*) discusses Moseley's investigations and records a series of experiments on rabbits, cats, dogs, sheep, and man, for the most part made with extracts, from which he draws the conclusion that *E. ageratoides* is not the cause of milk sickness.[1]

Brooks in 1914 (*2*) states that his experiments show that both cattle and sheep are poisoned by the plant, the sheep being the more susceptible. He states that an animal must eat about 10 per cent of its weight in order to be poisoned.

Clay (*3*) fed two head of cattle and one sheep on fresh-cut material of the plant, and all died within three days with symptoms of trembles.

The results obtained by these authors were so concordant that it now seems strange that more importance was not attached to them. The experiments of Vermilya were especially conclusive. The fact that in the coves mentioned by Drake no bad results followed the pasturing of cattle is, of course, only negative evidence.

Even in the experiments by Crawford, from which he concluded that the plant was not harmful, an examination of the cases shows that of the eight rabbits tested with extracts four died and one other exhibited trembling of the muscles. The cat used was sick. The dog and sheep used showed no symptoms, but the doses given were very small. The same thing was true of the dose given to himself, for, granted that he weighed 150 pounds, the dosage was only 0.44 of 1 per cent of his weight.

[1] In 1909 (*11*) and 1910 (*12*), in papers intended to prove that aluminium phosphate in plants is the cause of milk sickness, Moseley details other successful experiments with feeding the plant to rabbits and cows and claims to have produced the disease in rabbits and cats from the milk of diseased animals, in cats by butter, and in cats from the meat of diseased rabbits.

Inasmuch as the experiments detailed in this paper show that the toxic dose for animals is from 6 per cent to 10 per cent of their weight, symptoms would hardly be expected from the small quantity which Crawford administered to himself, even if man were vastly more susceptible than the lower animals.

Apparently experimenters were so interested in discovering the cause of milk sickness that the fact was overlooked that, whether milk sickness were produced by *E. urticaefolium* or not, actual proof had been made repeatedly of the poisonous character of the plant. The experiments of this paper have confirmed the former work and given definite information in regard to symptoms and dosage.[1]

SUMMARY

(1) *Eupatorium urticaefolium* has for many years been considered by many people as the cause of milk sickness, or trembles, in cattle.

(2) Experimental work shows conclusively that the plant is toxic, and produces a definite line of symptoms bearing a close resemblance to those considered characteristic of trembles.

(3) Probably many, possibly most, cases of trembles in cattle and sheep are due to poisoning by *E. urticaefolium*.

(4) Under the term "milk sickness," or "trembles," are probably grouped at least two distinct things: one poisoning by *E. urticaefolium* and the other a bacterial disease.

LITERATURE CITED

(1) BARBEE, W. J.
1840. FACTS RELATIVE TO THE ENDEMIC DISEASE CALLED, BY THE PEOPLE OF THE WEST, MILK-SICKNESS. *In* West. Jour. Med. and Surg., v. 1, p. 178–190.

(2) BROOKS, E. W.
1914. MILK-SICKNESS. *In* Altamont News, Altamont, Ill., v. 33, no. 44, p. 1, 5.

(3) CLAY, A. J.
1914. PERSONAL AND CLINICAL EXPERIENCES WITH MILK SICKNESS. *In* Ill. Med. Jour., v. 26, no 2, p. 103–108.

(4) CRAWFORD, A. C.
1908. THE SUPPOSED RELATIONSHIP OF WHITE SNAKEROOT TO MILK SICKNESS, OR "TREMBLES." *In* U. S. Dept. Agr. Bur. Plant Indus., Bul. 121, p. 5–20, 1 pl.

(5) CURTIS, R. S., and WOLF, F. A.
1917. EUPATORIUM AGERATOIDES, THE CAUSE OF TREMBLES. *In* Jour. Agr. Research, v. 9, no. 11, p. 397–404, pl. 22–24. Literature cited, p. 404.

(6) DEWEY, J. S.
1854. [MILK SICKNESS.] *In* Northwest. Med. and Surg. Jour., v. 11 (n. s., v. 3), no. 12, p. 541–547.

[1] Since this paper was offered for publication, Curtis and Wolf (5) have published the details of careful feeding experiments at the North Carolina Experiment Station with *Eupatorium urticaefolium* upon sheep, by which they produced 13 fatal cases of "trembles." Had their work been known when this paper was prepared, it would have necessitated some slight changes in the introductory part. As, however, their results do not conflict in any way with those obtained by the writers, it has seemed best to leave the paper in its original form.

(7) DRAKE, Daniel.
1841. A MEMOIR ON THE DISEASE CALLED BY THE PEOPLE "TREMBLES" AND THE "SICK-STOMACH" OR "MILK SICKNESS"; AS THEY HAVE OCCURRED IN THE COUNTIES OF FAYETTE, MADISON, CLARK, AND GREEN IN THE STATE OF OHIO. *In* West. Jour. Med. and Surg., v. 3, no. 3, p. 161–226.

(8) JORDAN, E. O., and HARRIS, N. M.
1909. MILK SICKNESS. *In* Jour. Infect. Diseases, v. 6, no. 4, p. 401–491, 6 fig. Bibliography, p. 485–491.

(9) 1859. MILK SICKNESS. *In* 13th Ann. Rpt. Ohio State Bd. Agr., 1858, p. 670–675. Reprinted in 28th Ann. Rpt. Ohio State Bd. Agr., 1873, p. 489–494. 1874.

(10) MOSELEY, E. L.
1906. THE CAUSE OF TREMBLES IN CATTLE, SHEEP AND HORSES, AND OF MILK-SICKNESS IN PEOPLE. *In* Ohio Nat., v. 6, no. 4, p. 463–470; no. 5, p. 477–483.

(11) 1909. THE CAUSE OF TREMBLES AND MILKSICKNESS. *In* Med. Rec., N. Y., v. 75, no. 20, p. 839–844.

(12) 1910. ANTIDOTE FOR ALUMINUM PHOSPHATE, THE POISON THAT CAUSES MILK-SICKNESS. *In* Med. Rec., N. Y., v. 77, no. 15, p. 620–622.

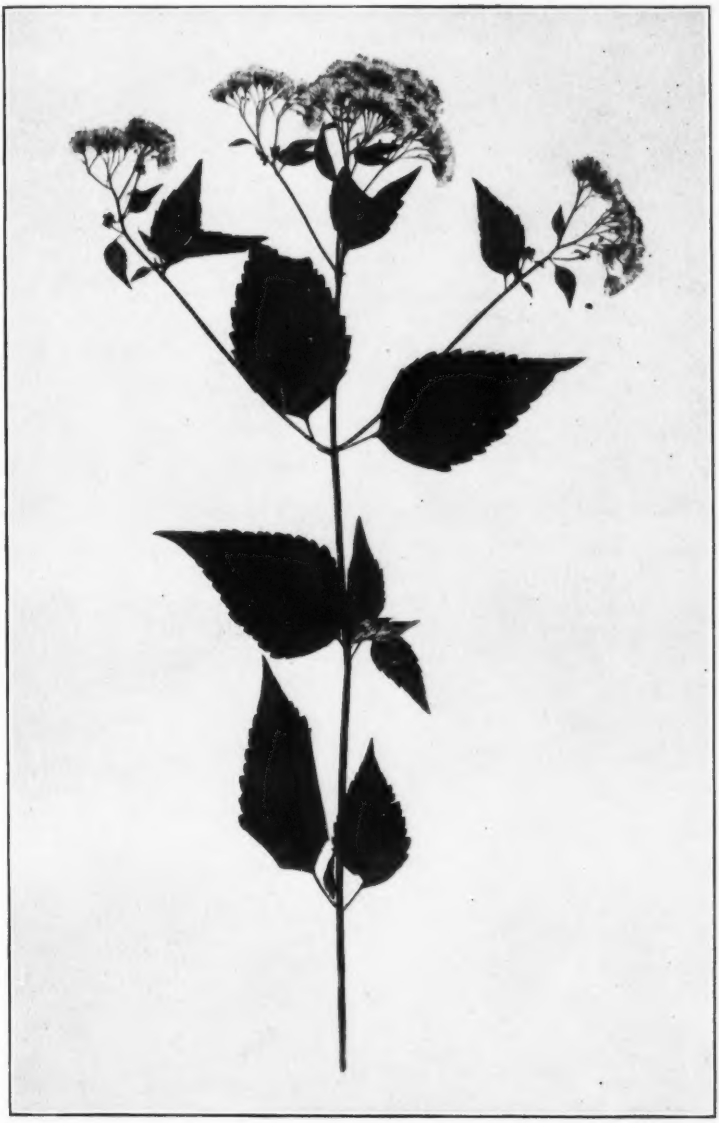
(13) 1867. THE PLANT THAT CAUSES MILK SICKNESS. *In* Med. and Surg. Reporter, v. 16, no. 3 (no. 526), p. 270–271. Reprinted from Missouri Republican.

(14) ROWE, John.
1839. [MILK SICKNESS.] *In* Ohio State Jour., Sept. 6. Cited in 13th Ann. Rpt. Ohio State Bd. Agr., 1858, p. 675. 1859.

PLATE 52

Eupatorium urticaefolium, white snakeroot.

(716)



A

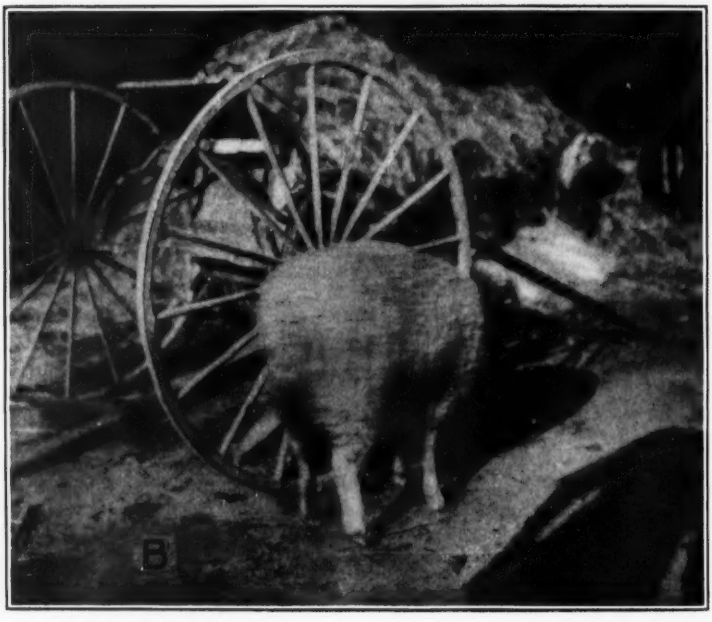

B

PLATE 53

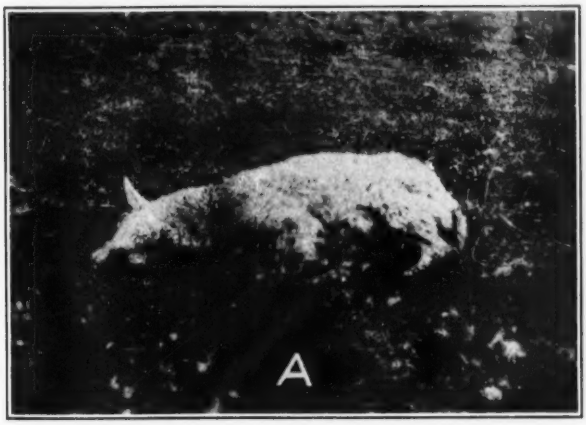
Poisoning by *Eupatorium urticaefolium:*

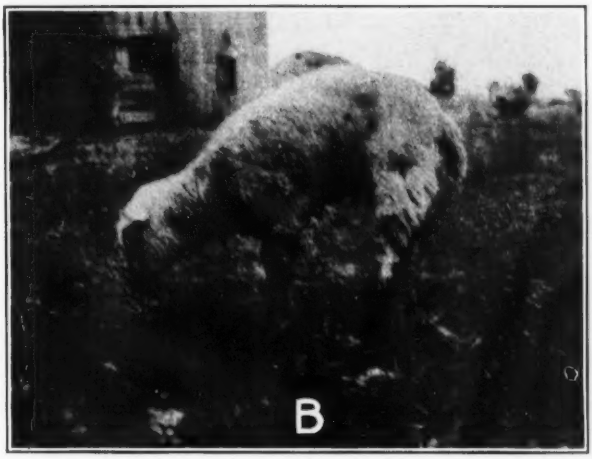
A.—Sheep 309, showing weakness.
B.—Sheep 309, showing trembling.

PLATE 54

Poisoning by *Eupatorium urticaefolium:*

A.—Sheep 367 at 11.17 a.m. on September 30.
B.—Sheep 367 at 11.20 a.m. on September 30.


A


B

A

B

PLATE 55

Poisoning by *Eupatorium urticaefolium*.

A.—Sheep 368 on September 24.
B.—Sheep 368 a little later the same day.

23719°—17——4

INDEX

Abies— Page
amabilis, reproduction from seed stored in forest floor ... 3–26
grandis, reproduction from seed stored in forest floor ... 3–26
nobilis, reproduction from seed stored in forest floor ... 3–26
Acid—
hydrocyanic—
amount absorbed by plants during fumigation ... 320
fumigation, effect on—
enzyms of plants ... 321–324
growth of plants ... 328–330
permeability of leaves of plant ... 331–333
photosynthesis of plants ... 326
physiology of plants ... 319–338
translocation of food in plants ... 326–327
transpiration of plants ... 333–338
respiration in plants ... 324–326
gas—
absorption by soil ... 430–434
absorption by water ... 430
effect on—
insects ... 421, 423, 428
plants ... 331–333, 421, 423–428
penetration of plants by ... 319–320
physical-chemical action in soil ... 428
soil fumigation ... 421–436
phosphoric—
determination of content in *Chrysanthemum cinerariaefolium* ... 79–81
relation to manganese content in *Chrysanthemum cinerariaefolium* ... 80–81
relation to presence of lipase in butter ... 444–445
soil, ratios between calcium oxid and iron oxid and aluminium oxid in ... 661–664
Aeration, effect on—
accumulation of nitrate nitrogen in soil ... 53
Jonathan-spot ... 291–293
Agallia sp., effect of hydrocyanic-acid gas on. 423
Agaricus—
arvensis, cause of fungus fairy rings ... 194
campestris, cause of fungus fairy rings ... 202
tabularis—
ammonia in rings of ... 222, 224
carbon in rings of ... 219–220
cause of fungus fairy rings ... 198
distribution of mycelium in soil ... 217
moisture content in rings of ... 226–228
mycelium, effect on soil ... 218–229
nitrogen in rings of ... 222–224
soil-moisture content in rings of ... 226–229, 236–237
Alfalfa. See *Medicago sativa*.
Alkaline soil, ratios between calcium oxid and iron oxid and aluminium oxid in ... 661–664
Alternaria spp., relation of Jonathan-spot to. 288
Aluminium Page
calcium, and iron, relationship in soils ... 662–672
effect of soluble salts on ... 544–546
oxid, ratios, with calcium oxid and iron oxid in soils ... 661–664
Alway, F. J., Klein, M. A., and McDole, G. R. (paper): Some Notes on the Direct Determination of the Hygroscopic Coefficient ... 147–166
Amanita—
muscaria, cause of fungus fairy rings ... 194
phalloides, cause of fungus fairy rings ... 194
Amaranthus blitoides, effect of fungus fairy rings on ... 239
Ammonia, in soil of fungus fairy rings ... 221–225
Anesthetic, effects on permeability of leaves of plants ... 331–333
Antigen, use in diagnosis of glanders ... 67–71
Aphis, grapevine. See *Macrosiphum illinoisensis*.
Aplanobacter—
agropyri, disease caused by, comparison with bacterial-blight of *Hordeum* spp. ... 627
rathayii, disease caused by, comparison with bacterial-blight of *Hordeum* spp. ... 627
Apple. See *Malus sylvestris*.
Apple-scald—
effect of—
aeration on ... 299–308
delayed storage on ... 311–312
humidity on ... 299–308
temperature on ... 295–299
relation—
of the maturity of fruit on ... 308–311
to rot infection ... 294–295
Armsby, H. P., and Fries, J. A. (paper): Influence of the Degree of Fatness of Cattle upon Their Utilization of Feed ... 451–472
Arny, A. C. and Hayes, H. K. (paper): Experiments in Field Technic in Rod Row Tests ... 399–419
Artemisia frigida, effect of fungus fairy rings on ... 237, 240
Ascaris—
lumbricoides—
infection of lungs of man by ... 395–398
life history ... 395–398
suilla, infection of lungs of pigs by ... 395–398
suum, infection of lungs of pig by ... 395–398
Avena sativa—
as green manure, effect on decomposition of organic matter in soil ... 679–697
bacterial disease of, resemblance to bacterial-blight of *Hordeum* spp. ... 629
effect of fungus fairy rings on ... 232
effect of sulphur on ... 94–98, 100–102
Mann's bladeblight of, comparison with bacterial-blight of *Hordeum* spp. ... 627–628
technic in rod row tests ... 402, 406, 409–414

Page

Bacteria—
cause of blight of *Hordeum* spp..... 625–643
relation to milk sickness..... 710–711
Bacterial-Blight of Barley (paper)..... 625–644
Bacterial-blight of *Hordeum* spp.—
comparison with similar bacterial diseases..... 627–628, 629
control..... 641
development..... 628
varietal susceptibility..... 629–631
Bacterium translucens—
causal organism of bacterial-blight of *Hordeum* spp..... 625–644
control..... 641
cultural characters..... 633–635
description..... 636
desiccation..... 636
dissemination..... 639–641
effect on host tissue..... 639
hosts of..... 629
inoculation of *Hordeum* spp. by..... 637–638
isolation..... 631–633
morphology..... 633
n. sp..... 636
overwintering..... 639–641
parasite of *Hordeum* spp..... 625–644
reinfection..... 631–633
susceptibility to mercuric chlorid..... 636
temperature relations..... 635–636
Baker, A. C. (paper): Life History of Macrosiphum illinoisensis, the Grapevine Aphis. 83–90
Barley. See *Hordeum* spp.
Bean, velvet. See *Stizolobium deeringianum.*
Blight, bacterial, of *Hordeum* spp.—
comparison with similar bacterial diseases..... 627–628
control..... 641
development..... 628
occurrence..... 628–631
varietal susceptibility..... 629–631
Blister-rust, white-pine, diagnosis—
importance of haustoria in..... 284–286
importance of mycelial characters in..... 284–286
importance of parasites in..... 284–286
Boletopsis cavipes, cause of fungus fairy rings. 194
Boletus spp., causes of fairy rings..... 194
Boneset, syn. White snakeroot.
Bordeaux mixture, use as control for endrot of *Oxycoccus macrocarpus*..... 39–40
Borer, three-lined fig-tree. See *Ptychodes trilineatus*..... 371–382
Bouteloua gracilis, effect of fungus fairy rings on..... 239–240
Brassica—
oleracea, penetration by *Fusarium conglutinans*..... 576–578
rapa—
dried, analysis..... 359–361
effect of hydrocyanic-acid gas on..... 423–428
reactions of phosphorus in root of..... 359–370
Breeding, plant, technic in..... 399–419
Breeding Sweet Corn Resistant to the Corn Earworm (paper)..... 549–572

Page

Brooks, Charles, and Cooley, J. S. (paper): Effect of Temperature Aeration and Humidity on Jonathan-Spot and Scald of Apples in Storage..... 287–318
Buhach. See *Chrysanthemum cinerariaefolium.*
Bulbilis dactyloides, effect of fungus fairy rings on..... 240
Burn, restocking by seed stored in forest floor. 1–26
Butter—
catalase in..... 446–447
enzyms of..... 437–450
galactase in..... 442–444
lipase in..... 444–445
oxidase content..... 445, 447
peroxidase content..... 446–447

Cabbage. See *Brassica oleracea.*
Calcium—
effect of soluble salts on..... 544–546
iron, and aluminium, relationship in soils. 662–671
oxid, ratios with iron oxid, aluminium oxid in soils..... 661–664
See also Lime.
Caldesiella ferruginosa, cause of fungus fairy rings..... 196
Calvatia—
cyanthiformis—
ammonia in rings of..... 223
cause of fungus fairy rings..... 201–202
nitrogen in rings of..... 223
soil-moisture content in rings of..... 228
fragilis, cause of fungus fairy rings..... 202
polygonia, cause of fungus fairy rings..... 202
Camphor. See *Cinnamomum camphora.*
Cantharellus—
aurantiacus, cause of fungus fairy rings..... 194
cibarius, cause of fungus fairy rings..... 194
cinerus, cause of fungus fairy rings..... 194
Carbohydrate, fermentation in cattle, relation of production of combustible gases to..... 455
Carbon—
amount evolved as carbon dioxid in treated soils..... 680–697
content in soil of fungus fairy rings..... 219–220
dioxid—
excretion in cattle..... 469
See also Carbon.
loss in excreta of cattle..... 453–455, 468
Casease. See Galactase.
Catalase—
content of butter..... 446–447
content of milk..... 446
in plants, effect of hydrocyanic acid on.. 323–324
Catastoma subterraneum, cause of fungus fairy rings..... 194, 202
Cattle—
combustible-gas production in—
relation to amount of feed..... 455
relation t carbohydrate fermentation..... 455
energy expenditure as result of feed consumption..... 455–460
energy, metabolizable..... 456–457, 460
excretions in urine..... 454–455, 467–468

Page

Cattle—Continued.
feed—
digestibility ... 453–454
net energy values ... 461–463
relation of body increase to ... 457
relation to chemical energy ... 457
relation to metabolizable energy ... 456–457
utilization, influence of fatness on ... 451–472
gaseous excretion ... 453, 469
heat emission and production ... 458–459, 471–472
lethal dose of *Eupatorium urticaefolium* for ... 706
maintenance requirement ... 460–461
methane production in ... 455, 469
production of epidermal tissue in ... 468
temperature during fattening ... 470–472
toxic dose of *Eupatorium urticaefolium* on ... 706
See also Cow, dairy; Steer.
Cedar, western red. See *Juniperus occidentalis*.
Cenangium urceolatum, resemblance to *Fusicoccum putrefaciens* ... 39
Chenopodium incanum, effect of fungus fairy rings on ... 239
Chloridea obsoleta—
breeding of *Zea mays* for resistance to ... 549–572
injury to *Zea mays* by ... 549–572
instincts ... 569–570
protective characters of *Zea mays* against ... 550–568
Chloroform—
influence on proteolysis of milk ... 440–441
permeability of leaves of *Lycopersicon esculentum* under influence of ... 332
Chrysanthemum—
cinerariaefolium, analyses ... 79–81
sp., effect of hydrocyanic-acid gas on ... 426–428
Cinnamomum camphora—
host plant of *Tylenchus penetrans* ... 27–30
injury caused by *Tylenchus penetrans* ... 30
Clavaria sp., cause of fungus fairy rings ... 194
Clawson, A. B., and Marsh, C. D. (paper): Eupatorium urticaefolium as a Poisonous Plant ... 699–715
Climate, relation to growth of—
cranberry fungi ... 522
Oxycoccus macrocarpus ... 521–529
Clitocybe spp., causes of fairy rings ... 194, 195
Clover—
as green manure, effect on decomposition of organic matter in soil ... 679–697
red. See *Trifolium pratense*.
Cobb, N. A. (paper): A New Parasitic Nema, Tylenchus penetrans, Found Infesting Cotton and Potatoes ... 27–33
Colley, Reginald H. (paper): Diagnosing White-Pine Blister-Rust from Its Mycelium ... 281–286
Collins, G. N. and Kempton, J. H. (paper): Breeding Sweet Corn Resistant to the Corn Earworm ... 549–572
Collybia—
confluens, cause of fungus fairy rings ... 195
sp., cause of fungus fairy rings ... 195
Complement fixation, use in conjunction with conglutination test for glanders ... 65–74
Concrete slabs, reinforced, tests ... 505–520

Page

Conglutination test, technic ... 67–71
Conglutination Test for the Diagnosis of Glanders (paper) ... 65–75
Cooley, J. S., and Brooks, Charles (paper): Effect of Temperature Aeration and Humidity on Jonathan-Spot and Scald of Apples in Storage ... 287–318
Corn. See *Zea mays*.
Corn earworm. See *Chloridea obsoleta*.
Cortinarius spp., causes of fairy rings ... 195
Cotton. See *Gossypium* spp.
Cow—
dairy, influence of age on milk ... 647–656
See also Cattle.
serum. See Serum, cow.
Cranberry. See *Oxycoccus macrocarpus*.
Cronartium ribicola—
causal organism of white-pine blister-rust ... 281–286
character of mycelium ... 284–285
method of parasitism ... 285–286
Cryptanthe crassisepala, effect of fungus fairy rings on ... 239

Dahlberg, A. C., and Thatcher, R. W. (paper): Enzyms of Milk and Butter ... 437–450
Decomposition of Green and Stable Manures in Soil (paper) ... 677–698
Deerwort, syn. White snakeroot.
DeOng, E. R. (paper): Hydrocyanic-Acid Gas as a Soil Fumigant ... 421–436
Diabrotica soror, effect of hydrocyanic-acid gas on ... 423
Diagnosing White-Pine Blister-Rust from Its Mycelium (paper) ... 281–286
Diaporthe phaseolorum—
cause of pobdlight of *Phaseolus lunatus* ... 473–504
cultural characteristics ... 492–494
dissemination ... 491–492
effect of light on growth ... 494–495
influence of temperature on growth ... 495
influence of toxic agents on germination of spores ... 496–500
inoculation of *Phaseolus lunatus* with ... 485–488
mode of infection of *Phaseolus lunatus* by ... 489–491
viability ... 489
Drainage—
effect of pumping from shallow well in relation to ... 339–357
relation to rainfall ... 248–279
Duff, effect of burning on natural reproduction of seed ... 1–26

Earworm, corn. See *Chloridea obsoleta*.
Eckles, C. H., and Palmer, L. S. (paper): Influence of the Age of the Cow on the Composition and Properties of Milk and Milk Fat ... 645–658
Effect of Pumping from a Shallow Well on the Ground-Water Table (paper) ... 339–357
Effect of Sulphur on Different Crops and Soils (paper) ... 91–103
Effect of Temperature Aeration and Humidity on Jonathan-Spot and Scald of Apples in Storage (paper) ... 287–318
Elder, black. See *Sambucus canadensis*.
Endrot of Cranberries (paper) ... 33–42

Page

Endrot of *Oxycoccus macrocarpus*—
causal organism ... 36–38
characteristics ... 36
control ... 39–40
Energy—
chemical, relation to feed consumed by cattle ... 457
loss in excreta of cattle ... 454–456, 462–463, 468
metabolizable, relation to feed consumed by cattle ... 456–457
Enzym—
in butter, relation to deterioration during storage ... 447
milk and butter, comparison ... 447
Enzyms of Milk and Butter (paper) ... 437–450
Errata ... IV
Ether, effect on permeability of leaves of *Lycopersicon esculentum* ... 332
Eupatorium—
ageratoides, syn. *Eupatorium urticaefolium*.
perfoliatum, resemblance to *Eupatorium urticaefolium* ... 700
urticaefolium—
cause of milk sickness ... 699–716
description ... 700
distribution ... 700
lethal dose ... 706
resemblance of *Eupatorium perfoliatum* to ... 700
toxic dose ... 706
use as medicine ... 700
Eupatorium urticaefolium as a Poisonous Plant (paper) ... 699–716
Evaporation, moisture, effect on movement of soluble salts through soils ... 543–544
Experiments in Field Technic in Rod Row Tests (paper) ... 399–419

Fairbank, H. S., and Goldbeck, A. T. (paper): Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads ... 505–520
Fairy ring, fungus. See Fungus fairy ring.
Farm crop plot tests, technic in ... 399–419
Feed, cattle—
digestibility ... 453–454, 465–467
net energy values in ... 461–463
Festuca octoflora, effect of fungus fairy rings on ... 229–237, 239–240
Ficus carica, host plant of *Ptychodes trilineatus* ... 371–382
Field technic in rod row tests ... 399–419
Fig. See *Ficus carica*.
Fir—
Douglas. See *Pseudotsuga taxifolia*.
lowland or "grand." See *Abies grandis*.
noble. See *Abies nobilis*.
silver. See *Abies amabilis*.
whitebark. See *Pinus albicaulis*.
Fire, forest—
effect on natural reproduction of seed ... 1–26
See also Burn.
Flax. See *Linum usitatissimum*.
Flaxwilt: A Study of the Nature and Inheritance of Wilt Resistance (paper) ... 573–606
Flaxwilt. See also *Fusarium lini*.

Page

Florida velvet bean. See *Stizolobium deeringianum*.
Fly, house. See *Musca domestica*.
Forest, natural reproduction of ... 1–26
Foster, W. D., and Ransom, B. H. (paper): Life History of Ascaris lumbricoides and Related Forms ... 395–398
Freezing-point lowering, induced by soluble salts, determination of ... 535–545
Fries, J. A., and Armsby, H. P. (paper): Influence of the Degree of Fatness of Cattle upon Their Utilization of Feed ... 451–472
Fumigation—
plant, with hydrocyanic-acid gas ... 319–338
soil—
with hydrocyanic-acid gas ... 421–426
with sodium cyanid ... 432–434
Fungus, relation of temperature to growth on *Oxycoccus macrocarpus* ... 521–529
Fungus, cause of fairy rings ... 191–246
Fungus fairy ring—
advance ... 204–208, 214–217
age ... 214–217
ammonia in soil of ... 221–225
carbon in soil of ... 219–220
cause ... 192–196
death of vegetation in ... 236–237
distribution ... 203–204
effect of—
cultivation on ... 233
soil moisture on fruiting bodies ... 208–217
weather on fruiting bodies ... 208–217
effect on—
chlorophyll content of plants in ... 235–236
grazing ... 233
physical changes in soil ... 225
revegetation ... 238–240
vegetation ... 229–237
eradication ... 237–238
nitrogen in soil of ... 220
soil-moisture in ... 226–229, 236–237
stimulated growth in ... 233–235
succession induced by ... 238–240
types ... 196–203
Fungus Fairy Rings in Eastern Colorado and Their Effect on Vegetation (paper) ... 191–246
Fusarium—
conglutinans—
penetration of *Brassica oleracea* by ... 576–578
penetration of *Linum usitatissimum* by ... 576–578
lini—
causal organism of flaxwilt ... 573–606
inheritance through hybridization of resistance to ... 588–600
mode of penetration of *Linum usitatissimum* by ... 575–579
probable factors in wilting of *Linum usitatissimum* by ... 581
relation to tissues of *Linum usitatissimum* ... 579–588
putrefaciens—
causal organism of endrot of *Oxycoccus macrocarpus* ... 36–38
control ... 39–40
cultural characters ... 39–41

Page

Fusarium—Continued
putrefaciens—continued
description ... 36–38
distribution ... 35
life history ... 38–39
n. sp ... 36
parasite of *Melilotus alba* ... 39
resemblance of *Cenangium urceolatum* to. 39
temperature index of ... 525–528

Gainey, P. L., and Metzler, L. F. (paper): Some Factors Affecting Nitrate-Nitrogen Accumulation in Soil ... 43–64
Galactase—
in butter ... 442–444
in milk ... 442
Gas—
combustible, production in cattle—
relation to carbohydrate fermentation .. 455
relation to feed ... 455
hydrocyanic-acid. See Acid, hydrocyanic, gas.
Genetic factors of *Pisum* spp., interrelation of ... 167–190
Georgia velvet bean. See *Stizolobium deeringianum*.
Geranium. See *Pelargonium* spp.
Gerlaugh, P., and Severson, B. O. (paper): A Statistical Study of Body Weights, Gains, and Measurements of Steers during the Fattening Period ... 383–394
Germination—
effect of hydrocyanic-acid gas on ... 423–425
seed stored in forest floor ... 1–26
Glanders, conglutination test for diagnosis .. 65–75
Glomerella cingulata—
relation of apple-scald to infection by 294–295
temperature index of ... 525–528
Goldbeck, A. T., and Fairbank, H. S. (paper): Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads ... 505–520
Gossypium spp.—
host of *Tylenchus penetrans* ... 27, 29, 30
injury caused by *Tylenchus penetrans* ... 29, 30
Grains, small, technic in rod row tests 399–419
Grape, wild. See *Vitis* spp.
Grapevine aphis. See *Macrosiphum illinoisensis*.
Grass—
effect of fungus fairy rings on ... 191–246
orchard, Rathay's disease of, comparison with bacterial-blight of *Hordeum* spp 627
western-wheat, O'Gara's disease of, comparison with bacterial-blight of *Hordeum* spp ... 627
Grindelia squarrosa, effect of fungus fairy rings on ... 237
Ground-water table, effect of pumping from shallow well on ... 339–357
Gutierrezia sarothrae, effect of fungus fairy rings on ... 237, 240

Hammett, F. S., et al. (paper): Reactions of the Phosphorus of the Thickened Root of the Flat Turnip ... 359–370

Page

Harter, L. L. (paper): Podlight of the Lima Bean Caused by Diaporthe phaseolorum. 473–504
Hartwell, B. L., Hammett, F. S., and Wessels, P. H. (paper): Reactions of the Phosphorus of the Thickened Root of the Flat Turnip ... 359–370
Hayes, H. K. and Arny, A. C. (paper): Experiments in Field Technic in Rod Row Tests ... 399–419
Hebeloma crustuliniforme, cause of fungus fairy rings ... 195
Hedeoma nana, effect of fungus fairy rings on ... 229–237
Helminthosporium gramineum, disease caused by, resemblance to bacterial-blight of *Hordeum* spp ... 625–627
Hemlock, western. See *Tsuga heterophylla*.
Hilgard, E. W., method for determination of hygroscopic coefficient ... 150–151, 152, 163–164
Hofmann, J. V. (paper): Natural Reproduction from Seed Stored in the Forest Floor .. 1–26
Hordeum spp.—
bacterial-blight of—
appearance ... 625–627
comparison with similar bacterial diseases ... 627–628, 629
development ... 628
occurrence ... 628–631
varietal susceptibility ... 629–631
host plant of *Bacterium translucens* ... 625–644
inoculation with *Bacterium translucens* ... 637–638
Hordeum vulgare, technic in rod row tests .. 402–417
Horse serum. See Serum, horse.
Horton, J. R. (paper): Three-Lined Fig-Tree Borer ... 371–382
House fly. See *Musca domestica*.
Humidity, effect on Jonathan-spot ... 291–293
Hybridization, inheritance of wilt resistance of *Linum usitatissimum* through ... 588–600
Hydnum spp., causes of fairy rings ... 195, 196
Hygrophorus virgineus, cause of fungus fairy rings ... 195
Hydrocyanic acid. See Acid, hydrocyanic.
Hydrocyanic-acid gas. See Acid, hydrocyanic, gas.
Hydrocyanic-Acid Gas as a Soil Fumigant (paper) ... 421–436
Hydrogen peroxid, determination of catalase—
in butter by reaction with ... 446
in milk by reaction with ... 446
Hygroscopic coefficient—
direct determination in soil ... 147–165
Hilgard's method for determination in soil ... 150, 151, 152, 163–164
influence of—
grinding on ... 159
size of containers on ... 159–160
temperature on ... 156–159
time of exposure on ... 156

Indian corn. See *Zea mays*.
Indian sanicle, syn. White snakeroot.
Influence of the Age of the Cow on the Composition and Properties of Milk and Milk Fat (paper) ... 645–658

Page

Influence of the Degree of Fatness of Cattle upon Their Utilization of Feed (paper).. 451-472
Inheritance Studies in Pisum. IV. Interrelation of the Genetic Factors of Pisum (paper)..... 167-190
Inocybe sp., cause of fungus fairy rings..... 195
Insect flower. See *Chrysanthemum cinerariaefolium.*
Insect powder. See *Chrysanthemum cinerariaefolium.*
Iron in soils—
effect of soluble salts on..... 544-546
relation to calcium and aluminum.... 662-671
Iron oxid, ratios with calcium oxid and aluminum oxid in soils..... 661-664
Irrigation—
effect of pumping from shallow well in relation to..... 339-357
effect on fungus fairy rings..... 237

Johnson, A. G., et al. (paper): Bacterial-Blight of Barley..... 625-644
Jonathan-spot—
description..... 288
effect of—
aeration on..... 291-293
humidity on..... 291-293
maturity of fruit on..... 293-294
temperature on..... 289-291
relation to apple rots..... 288
Jones, L. R., Johnson, A. G., and Reddy, C. S. (paper): Bacterial-Blight of Barley... 625-644
Juniperus spp., reproduction from seed stored in forest floor..... 1-26

Kempton, J. H., and Collins, G. N. (paper): Breeding Sweet Corn Resistant to the Corn Earworm..... 549-572
Klein, M. A., et al. (paper): Some Notes on the Direct Determination of the Hygroscopic Coefficient..... 147-166

Lactacius insulsus, cause of fungus fairy rings. 195
Lactalbuminase. See Galactase.
Lactarius—
piperatus, cause of fungus fairy rings..... 195
torminosus, cause of fungus fairy rings..... 195
Lactuca sativa, effect of hydrocyanic-acid gas..... 423-428
Lamb—
growth during first year..... 607-624
measurements..... 608-624
Lappula occidentale, effect of fungus fairy rings on..... 239
Leaf hopper. See *Agallia* sp.
Lepiota—
morgani, cause of fungus fairy rings..... 203
procera, cause of fungus fairy rings..... 195
Lettuce. See *Lactuca sativa.*
Life History of Ascaris lumbricoides and Related Forms (paper)..... 395-398
Life History of Macrosiphum illinoisensis, the Grapevine Aphis (paper)..... 83-90
Lime—
conservation of by manure..... 686
effect on decomposition of green manure. 680-698
effect on decomposition of stable manure. 680-698
requirement in acid soils..... 665-666

Page

Linum usitatissimum—
inheritance of wilt resistance through hybridization..... 588-600
loss of, caused by *Fusarium lini*..... 573
penetration by *Fusarium* spp..... 575-579
probable factors in wilting of..... 581
relation of tissues to *Fusarium lini*..... 579-588
wilt of..... 573-606
Lipase, in butter..... 444-445
Lipman, C. B., method for determination of hygroscopic coefficient..... 151
Louisiana, southern, run-off from drained prairie lands of..... 247-279
Lungs, infection by *Ascaris* spp..... 395-398
Lycoperdon spp., causes of fairy rings..... 195-202
Lycopersicon esculentum, effect of—
anesthetics on permeability of leaves of.. 331-333
hydrocyanic-acid fumigation on—
composition of..... 328
enzymic activities of..... 321-324
growth of..... 328-330
permeability of leaves of..... 331-333
respiration of..... 324-326
translocation of food in..... 326-327
transpiration of..... 333-335

Macrosiphum illinoisensis—
distribution..... 83
food plants..... 83
life history..... 83-90
nomenclature..... 83
Magnesium in soils, effect of soluble salts on..... 544-546
Malus sylvestris—
relation of Jonathan-spot to rots of..... 288
scald of..... 294-295
Malvastrum coccineum, effect of fungus fairy rings on..... 237, 239
Manganese, occurrence in *Chrysanthemum cinerariaefolium*..... 77-82
Mann's bladeblight of oats, comparison with bacterial-blight of *Hordeum* spp..... 627-628
Manure—
green, decomposition in soil..... 677-698
stable, decomposition in soil..... 677-698
Marasmius—
oreades, cause of fungus fairy rings..... 195, 202
urens, cause of fungus fairy rings..... 195
Marsh, C. D. and Clawson, A. B. (paper): Eupatorium urticaefolium as a Poisonous Plant..... 699-715
McCool, M. M., and Wheeting, L. C. (paper): Movement of Soluble Salts through Soils. 531-547
McDole, G. R., et al. (paper): Some Notes on the Direct Determination of the Hygroscopic Coefficient..... 147-166
McDonnell, C. C., and Roark, R. C. (paper): Occurrence of Manganese in Insect Flowers and Insect Flower Stems..... 77-82
Medicago sativa, effect of—
hydrocyanic-acid gas on..... 423-428
sulphur on..... 94-103
Melilotus alba, host plant of *Fusicoccum putrefaciens*..... 39
Methane, production of, in cattle..... 455, 469
Metzler, L. F. and Gainey, P. L. (paper): Some Factors Affecting Nitrate-Nitrogen Accumulation in Soil..... 43-64

Page

Milk—
catalase in... 446
composition of, in aged cows... 655–656
enzyms... 437–450
fat, influence of age of cow on... 647–655
galactase in... 442
influence of age of cow on... 645–657
oxidase in... 445
peroxidase in... 446–447
properties of, in aged cows... 655–656
sickness, disease of animals caused by *Eupatorium urticaefolium*... 699–716
Moisture, soil—
effect of variations upon nitrate accumulation... 48–57
effect on *Agaricus tabularis*... 226–229, 236–237
hygroscopic, rate of loss... 153–154
relation to movement of soluble salts... 543–544
Moore, William, and Willaman, J. J. (paper): Studies in Greenhouse Fumigation with Hydrocyanic Acid... 319–338
Morchella—
esculenta, cause of fungus fairy rings... 195
hybrida, cause of fungus fairy rings... 195
Movement of Soluble Salts through Soils (paper)... 531–547
Mule serum. See Serum, mule.
Musca domestica, effect of hydrocyanic-acid gas on... 422–423

Natural Reproduction from Seed Stored in the Forest Floor (paper)... 1–26
Nature and Rate of Growth in Lambs During the First Year (paper)... 607–624
Nema—
method of measuring... 33
parasitic... 27–33
Nematode. See Nema.
New Parasitic Nema, Tylenchus penetrans, Found Infesting Cotton and Potatoes, A (paper)... 27–33
Nicotiana tabacum, effect of hydrocyanic-acid fumigation on photosynthesis of... 326
Nitrate-nitrogen, factors affecting accumulation in soil... 43–64
Nitrification, soil... 43–64
Nitrogen—
determination in *Chrysanthemum cinerariaefolium*... 79–81
determination in fungus fairy ring soil... 220–225
loss in excreta of cattle... 453–455, 468
nitrate, factors affecting accumulation in soil... 43–64
relation to manganese content in *Chrysanthemum cinerariaefolium*... 80–81
soluble—
influence of chloroform on proteolysis of milk as indicated by... 440–441
presence of galactase in butter as shown by increase of... 442–444
presence of galactase in milk as shown by increase of... 442–444

Oats. See *Avena sativa*.
Occurrence of Manganese in Insect Flowers and Insect Flower Stems (paper)... 77–82

Page

O'Gara's disease of western wheat-grass, comparison with bacterial-blight of *Hordeum* spp... 627
Okey, C. W. (paper): Run-off from the Drained Prairie Lands of Southern Louisiana... 247–279
Orchard-grass. See Grass, orchard.
Oxidase—
content of butter... 445, 447
content of milk... 445
in plants, effect of hydrocyanic acid on... 321–323
Oxycoccus macrocarpus—
daily normal temperatures in regions of... 523
endrot of—
causal organism... 36–38
characteristics... 36
control... 39–40
host plant of *Fusicoccum putrefaciens*... 35–41
length of frostless season in regions of... 522
rainfall in regions of... 521–522
relation of climate to fungus growth... 521–522
relation of rainfall to fungus growth... 521–529

Palmer, L. S. and Eckles, C. H. (paper): Influence of the Age of the Cow on the Composition and Properties of Milk and Milk Fat... 645–658
Paxillus involutus, cause of fungus fairy rings. 196
Pea. See *Pisum* spp.
Penicillium expansum, relation of—
apple-scale to infection by... 294–295
Jonathan-spot to... 288
Pelargonium spp., effect of hydrocyanic-acid fumigation on—
translocation of food in... 326–327
photosynthesis of... 326
Peroxidase content of milk and butter... 446–447
Phaseolus lunatus—
inoculation with *Diaporthe phaseolorum*... 485–488
mode of infection by *Diaporthe phaseolorum*... 489–491
podblight of—
caused by *Diaporthe phaseolorum*... 473–504
control... 500
description... 475–476
dissemination... 491–492
distribution... 474
etiology... 476–477
loss... 474
morphology... 479
prevalence... 474
resemblance to leafspot... 475
Phleum pratense, bacterial disease of, resemblance to bacterial-blight of *Hordeum* spp... 629
Phoma subcircinata, syn. *Diaporthe phaseolorum*.
Phosphoric acid. See Acid, phosphoric.
Phosphorus, reactions in root of *Brassica rapa*... 359–370
Phylloxera vastatrix, effect of hydrocyanic-acid gas on... 423
Picea engelmanni, reproduction from seed stored on forest floor... 15–26
Piemeisel, R. L., and Shantz, H. L. (paper): Fungus Fairy Rings in Eastern Colorado and their Effect on Vegetation... 191–246

Page

Pig, infection by *Ascaris* spp..... 398
Pine—
knobcone. See *Pinus attenuata.*
lodgepole. See *Pinus murrayana.*
western white. See *Pinus monticola.*
western yellow. See *Pinus ponderosa.*
white. See *Pinus strobus.*
Pinus—
albicaulis, reproduction from seed stored in forest floor.....15–26
attenuata, reproduction from seed stored in forest floor..... 25–26
monticola, reproduction from seed stored in forest floor..... 1–26
murrayana, reproduction from seed stored in forest floor..... 15–26
ponderosa, reproduction from seed stored in forest floor..... 15–26
strobus, host plant of *Cronartium ribicola*.. 281–286
Piper, C. V., and Shull, J. M. (paper): Structure of the Pod and the Seed of the Georgia Velvet Bean, Stizolobium deeringianum.. 673–676
Pisum spp.—
genetic factors—
effect of environment on expression of.. 171–173
inheritance studies..... 167–190
interrelation..... 167–190
linkage in..... 177
Plantago purshii, effect of fungus fairy rings on..... 229–237, 239–240
Plant breeding, technic in..... 399–419
Pluteus cervinus, cause of fungus fairy rings.. 196
Pneumonia, caused by Ascaris..... 397–398
Podblight of the Lima Bean Caused by Diaporthe phaseolorum, by L. L. Harter (paper)..... 473–504
Poisoning, by *Eupatorium urticaefolium*.... 699, 711
Poolroot, syn. White snakeroot.
Poolwort, syn. White snakeroot.
Potassium—
chlorid change in soil induced by..... 539–541, 543–544
cyanid, permeability of leaves of *Lycopersicon esculentum* under influence of..... 332
Potato. See *Solanum tuberosum.*
Potter, R. S., and Snyder, R. S. (paper): Decomposition of Green and Stable Manures in Soil..... 677–698
Prairie, drained, run-off from..... 247–279
Protein, milk, results of estimation of hydrolysis by ninhydrin method..... 440
Proteolysis, milk, influence of—
chloroform on..... 440–441
sodium chlorid on..... 441–442
Pseudomonas avenae, disease caused by, comparison with bacterial-blight of *Hordeum* spp..... 627–628
Pseudotsuga taxifolia, reproduction from seed stored in forest floor..... 1–26
Psoralea tenuiflora, effect of fungus fairy rings on..... 237
Ptychodes trilineatus—
biology..... 372–380
control..... 381–382
distribution..... 371
food plant of..... 371–382

Page

Ptychodes trilineatus—Continued
habits..... 372–380
injuriousness..... 371–372
life history..... 372–380
Pyrethrum. See *Chrysanthemum cinerariaefolium.*
Pyrogallol, estimation of oxidase in milk as shown by oxygen absorption of..... 445

Rainfall, relation to drainage..... 248–27
Ransom, B. H., and Foster, W. D. (paper): Life History of Ascaris lumbricoides and Related Forms..... 395–398
Rathay's disease of orchard-grass, comparison with bacterial-blight of *Hordeum* spp..... 627
Reactions of the Phosphorus of the Thickened Root of the Flat Turnip (paper)..... 359–370
Reddy, C. S., et al. (paper): Bacterial-Blight of Barley..... 625–644
Reproduction from seed stored in forest floor. 1–26
Richweed, syn. White snakeroot.
Rietz, H. L., and Smith, L. H. (paper): A Statistical Study of Some Indirect Effects of Certain Selections in Breeding Indian Corn..... 105–146
Ritzman, E. G. (paper): Nature and Rate of Growth in Lambs During the First Year. 607–624
Roark, R. C., and McDonnell, C. C. (paper): Occurrence of Manganese in Insect Flowers and Insect Flower Stems..... 77–82
Rod row tests—
competition between adjacent rows..... 404–412
technic in..... 399–419
value of replications for..... 412–417
Rot, apple—
apple-scald as source of..... 294–295
relation to Jonathan-spot..... 288
Run-Off from the Drained Prairie Lands of Southern Louisiana (paper)..... 247–279
Rust, white-pine blister. See Blister-rust, white-pine.
Rye. See *Secale cereale.*

Salts, soluble, movement through soils..... 531–547
Sambucus canadensis, reproduction from seed stored in forest floor..... 21–26
Sanicle—
Indian, syn. White snakeroot.
white, syn. White snakeroot.
Scald, apple. See Apple-scald.
Schedonnardus paniculatus, effect of fungus fairy rings on..... 239
Schoening, H. W. (paper): Conglutination Test for the Diagnosis of Glanders..... 65–75
Sclerotinia cinerea, relation of—
apple-scald to infection by..... 294–295
Jonathan-spot to..... 288
Secale cereale, bacterial disease of, resemblance to bacterial-blight of *Hordeum* spp..... 629
Seed in forest floor—
reproduction from..... 1–26
viability..... 1–26
Serum—
cow, titration..... 68–72
horse, test of, in diagnosis of glanders..... 72–73
mule, test of, in diagnosis of glanders..... 73–74

Page

Severson, B. O., and Gerlaugh, P. (paper): A Statistical Study of Body Weights, Gains, and Measurements of Steers during the Fattening Period 383–394
Shantz, H. L., and Piemeisel, R. L. (paper): Fungus Fairy Rings in Eastern Colorado and their Effect on Vegetation 191–246
Sharp, L. T., method for determination of hygroscopic coefficient 151
Shear, C. L. (paper): Endrot of Cranberries. 35–42
Shedd, O. M. (paper): Effect of Sulphur on Different Crops and Soils 91–103
Sheep—
  lethal dose of *Eupatorium urticaefolium* 706
  measurements 608–624
  red blood corpuscles, use in diagnosis of glanders 67–71
  toxic dose of *Eupatorium urticaefolium* for .. 706
  weight 608, 611, 612, 614
  See also Lamb.
Shull, J. M., and Piper, C. V. (paper): Structure of the Pod and the Seed of the Georgia Velvet Bean, Stizolobium deeringianum. 673–676
Silica, acid-soluble, determination of in soils 664–665
Siphonophora viticola, syn. *Macrosiphum illinoisensis*.
Sitanion hystrix, effect of fungus fairy rings on 239
Slab, concrete, tests 505–520
Slows, disease of animals caused by *Eupatorium urticaefolium* 699–716
Smith, L. H., and Rietz, H. L. (paper): A Statistical Study of Some Indirect Effects of Certain Selections in Breeding Indian Corn 105–146
Snakeroot, white. See *Eupatorium urticaefolium*.
Snyder, R. S. and Potter, R. S. (paper): Decomposition of Green and Stable Manures in Soil 677–698
Sodium—
  carbonate, changes in soil induced by. 542, 545, 546
  chlorid, changes in soil induced by 535–540, 544–546
  cyanid, fumigation of soil with 432–434
Soil—
  absorption of hydrocyanic-acid by 430–434
  acid—
    lime requirement of 665–666
    ratios between calcium oxid and iron oxid plus aluminium oxid in 661–664
  alkaline, ratios between calcium oxid and iron oxid plus aluminium oxid in 661–664
  character of, used in pumping from shallow well 339–340
  decomposition of manure in 677–698
  distribution of mycelium of *Agaricus tabularis* in 217
  effect of—
    compactness upon nitrate accumulation. 46–63
    depth of column upon nitrate accumulation 46–63
    on fruiting bodies in fungus fairy rings. 208–217
    sulphur on 91–103
  factors affecting accumulation of nitrate nitrogen in 43–64

Page

Soil—Continued
  fumigation—
    with hydrocyanic-acid gas 421–436
    with sodium cyanid 432–434
  Hilgard's method for determination of hygroscopic coefficient in 150, 151, 152, 163–164
  hygroscopic coefficient—
    influence of—
      grinding on 159
      of containers on 159–160
      temperature on 156–159
      time of exposure on 156
    Lipman and Sharp's method for determination of hygroscopic coefficient in 151
  moisture, effect on—
    Agaricus tabularis 236–237
    nitrate accumulation 48–63
  movement of soluble salts through 531–547
  mycelium of fairy rings in 217–229
  physical changes in, effect of fungus fairy rings on 225
  physical-chemical action of hydrocyanic-acid gas in 428–434
  rate of loss of hygroscopic moisture in 153–154
  treated, amount of carbon evolved as carbon dioxid in 680–697
Soil Acidity and the Hydrolytic Ratio in Soils (paper) 659–672
Soja max—
  effect of sulphur on 93, 95–103
  protein in 102
Solanum tuberosum—
  host of *Tylenchus penetrans* 27, 29, 30, 31
  injury caused by *Tylenchus penetrans* 29, 30
Some Factors Affecting Nitrate-Nitrogen Accumulation in Soil (paper) 43–64
Some Notes on the Direct Determination of the Hygroscopic Coefficient (paper) 147–166
Soybean. See *Soja max*.
Species, new 32, 36, 636
Spelt. See *Triticum spelta*.
Spruce, Englemann. See *Picea engelmanni*.
Spurway, C. H. (paper): Soil Acidity and the Hydrolytic Ratio in Soils 659–672
Squawweed, syn. White snakeroot.
Staining, double, method used in diagnosing white-pine blister-rust 281–284
Statistical Study of Body Weights, Gains, and Measurements of Steers during the Fattening Period (paper) 383–394
Statistical Study of Some Indirect Effects of Certain Selections in Breeding Indian Corn, A (paper) 105–146
Steer—
  body weight during fattening period 383–394
  measurements during fattening period ... 383–394
  See also Cattle.
Steria, syn. White snakeroot.
Stevens, Neil (paper): Temperatures of the Cranberry Regions of the United States in Relation to the Growth of Certain Fungi. 521–529
Stictocephala festina, effect of hydrocyanic-acid gas on 423
Stizolobium deeringianum—
  characteristic elements 675
  food value 673

Page

Stizolobium deeringianum—Continued.
structure of pod 673-674
structure of seed 674
Storage—
butter, factors in deterioration of 447-448
delay in, effect on apple-scald 311-312
Stripe disease of *Hordeum* spp., resemblance to bacterial-blight 625-627
Structure of the Pod and the Seed of the Georgia Velvet Bean, Stizolobium deeringianum (paper) 673-676
Studies in Greenhouse Fumigation with Hydrocyanic Acid: Physiological Effects on the Plant (paper) 319-338
Sulphur—
effect on different crops 91-103
sulphate—
effect on different crops 98-99
formation in seeds on germination 100
percentage in different crops 99-100
Swamp land, Gulf coast, use of rainfall data in drainage of 248

Taxus brevifolia, reproduction from seed stored in forest floor 3-26
Technic, field, in rod row tests 399-419
Temperature—
effect on apple-scald 295-299
effect on Jonathan-spot 289-291
index for *Fusicoccum putrefaciens* 525-528
index for *Glomerella cingulata* 525-528
influence on growth of *Diaporthe phaseolorum* 495
influence on soil hygroscopicity 156-159
of cattle during fattening 470-472
probable factor in wilt of *Linum usitatissimum* 581
relation to fungus growth on *Oxycoccus macrocarpus* 521-529
relation to growth of *Bacterium translucens* 635-636
Temperatures of the Cranberry Regions of the United States in Relation to the Growth of Certain Fungi (paper) 521-529
Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads (paper) 505-520
Tests, rod row. See Rod row tests.
Thatcher, R. W. and Dahlberg, A. C. (paper): Enzyms of Milk and Butter 437-450
Thoroughwort. See *Eupatorium perfoliatum*.
Three-lined Fig-Tree Borer (paper) 371-382
See also *Ptychodes trilineatus*.
Timothy. See *Phleum pratense*.
Tires, disease of animals caused by *Eupatorium urticaefolium* 699-716
Tisdale, W. H. (paper): Flaxwilt: A Study of the Nature and Inheritance of Wilt Resistance 573-606
Tomato. See *Lycopersicon esculentum*.
Tree hopper. See *Stictocephala festina*.
Tree, reproduction by seed stored in forest floor 1-26
Trembles, disease of animals caused by *Eupatorium urticaefolium* 699-716

Page

Tricholoma spp., causes of fairy rings 196, 202
Trifolium pratense, effect of sulphur on 94-102
Triticum—
aestivum, effect of sulphur on 94-98, 100-103
spp.—
bacterial disease of, resemblance to bacterial-blight of *Hordeum* spp 629
technic in rod row tests 403-404, 406-408, 409-416
effect of fungus fairy rings on 231
spelta, bacterial disease of, resemblance to bacterial blight of *Hordeum* spp 629
Tsuga heterophylla, reproduction from seed stored in forest floor 1-26
Turnip. See *Brassica rapa*.
Tobacco. See *Nicotiana tabacum*.
Tuber sp., cause of fungus fairy rings 196
Tylenchus penetrans—
control 31
description of 32
habitat 32
hosts of 30
identification 30
injury to plants by 29-30
losses from 30-31
muscular powers 31
n. sp 32
parasite of—
Cinnamomum camphora 27, 30
Gossypium spp 27, 29
Solanum tuberosum 27, 29, 30, 31
Viola spp 27, 29

Urine, cattle, excretions in 454-455, 467-468

Velvet bean—
Florida. See *Stizolobium deeringianum*.
Georgia. See *Stizolobium deeringianum*.
Violet. See *Viola* spp.
Viola spp.—
host of *Tylenchus penetrans* 27, 29
injury caused by *Tylenchus penetrans* 29, 30
Vitis spp.—
host plant of *Macrosiphum illinoisensis* ... 83
occurrence of *Macrosiphum illinoisensis* on 83

Wandering-Jew. See *Zebrina pendula*.
Water—
absorption of hydrocyanic-acid gas by 430
soil, effect on movement of soluble salts through 539-544
See also Irrigation; Moisture, soil.
Weather—
effect on fruiting bodies of fungus fairy rings 208-217
relation to—
growth of cranberry fungi 523
growth of *Oxycoccus macrocarpus* 521-524
infection of *Phaseolus lunatus* by *Diaporthe phaseolorum* 489-491, 495
See also Humidity; Rainfall; Temperature.
Weir, W. N. (paper): Effect of Pumping from a Shallow Well on the Ground-Water Table 339-357
Well, shallow, effect of pumping on ground-water table 339-357

Page

Western wheat-grass. See Grass, western-wheat.
Wheat. See *Triticum*.
Wheat-grass, western. See Grass, western-wheat.
Wessels, P. H., et al. (paper): Reactions of the Phosphorus of the Thickened Root of the Flat Turnip..... 359–370
Wheeting, L. C., and McCool, M. M. (paper): Movement of Soluble Salts through Soils. 531–547
White, O. E. (paper): Inheritance Studies in Pisum. IV. Interrelation of the Genetic Factors of Pisum..... 167–190
White pine. See *Pinus strobus*.
White-pine blister-rust. See Blister-rust, white-pine.
White sanicle, syn. White snakeroot.
White snakeroot. See *Eupatorium urticaefolium*.
Whitetop, syn. White snakeroot.
Wild grape. See *Vitis* spp.

Page

Willaman, J. J., and Moore, William (paper): Studies in Greenhouse Fumigation with Hydrocyanic Acid..... 319–338
Wilt, flax. See *Fusarium lini*.
Worm, corn ear. See Corn earworm.

Yew, Pacific. See *Taxus brevifolia*.

Zea mays—
breeding for resistance to *Chloridea obsoleta*..... 549–572
effect of hydrocyanic-acid gas on..... 423–428
indirect effects of selections in breeding. 105–146
protective characters against *Chloridea obsoleta*..... 550–568
selections for breeding with regard to—
chemical composition..... 105–146
physical characters..... 105–146
types..... 108–146
variability..... 108–146
Zebrina pendula, effect of hydrocyanic-acid gas on..... 426–428

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY